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RISK ANALYSIS IN SUPPORT OF THE CHEMICAL STOCKPILE DISPOSAL PROGRAM

DECEMBER 1987

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PROGRAM EXECUTIVE OFFICER-PROGRAM MANAGER
FOR CHEMICAL DEMILITARIZATION

ABERDEEN PROVING GROUND, MARYLAND 21010-5401

RISK ANALYSIS SUPPORTING THE CHEMICAL STOCKPILE DISPOSAL PROGRAM (CSDP)

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This document has been prepared for the U.S. Army to support the Final Programmatic Environmental Impact Statement for the Chemical Stockpile Disposal Program (CSDP). This report presents the results of the integrated risk analysis of the CSDP - a continuation of the "risk analyses" prepared by GA Technologies Inc. for this same program (Report Numbers SAPEO-CDE-IS-87008, SAPEO-CDE-IS-87009, and SAPEO-CDE-IS-87010). This report describes the risk analysis methodology, and presents the results of the risk analysis in a variety of ways, including: cumulative risk curves; expected fatalities values; individual risk data; estimates of time and person-years at risk; and, semi-quantitiative 'picto-graphical' comparisons of the major measures of both societal and individual risk. Differences in risk of the disposal alternatives are presented and discussed in light of the uncertainty in the analysis. Toxic Hazards.

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RISK ANALYSIS SUPPORTING
THE CHEMICAL STOCKPILE DISPOSAL PROGRAM (CSDP)

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ABSTRACT

The U.S. Army's Office of The Program Executive Officer, Program Manager for Chemical Demilitarization (PEO-PM Cml Demil) is responsible for the disposal of the Nation's stockpile of unitary chemical munitions -- a large-scale effort that, by Congressional mandate, must be completed by September 1994. The Army has proposed several alternatives for carrying out this Chemical Stockpile Disposal Program (CSDP), and is now in the process of preparing a programmatic environmental impact statement to assess the alternatives and support a decision by the Army in early 1988. MITRE is responsible for preparing the integrated risk analysis of the CSDP disposal alternatives, the purpose of which will be to estimate and display the risk of accidental chemical agent exposure of the public during the CSDP. This report describes the approach used by MITRE, and presents the results of the risk analysis in a variety of ways, including: cumulative risk curves; expected fatalities values; individual risk data; estimates of time and person-years at risk; and, semi-quantitative 'pictogram' comparisons of the major measures of both societal and individual risk. Differences in risk of the disposal alternatives are presented and discussed in light of the uncertainty in the analysis.

ACKNOWLEDGMENTS

The risk analysis described in this report is the collective product of many individuals and their organizations. The authors would like to recognize their contributions, all of which were essential to the successful completion of this study.

- GA Technologies (especially Mike Stamatelatos, Rick Bolig, Daisy Ligon, and Chet Everline) for the accident scenario definitions and characterizations as a basis for the risk analysis:

- Oak Ridge National Laboratory (especially Sam Carnes, Frank Kornegay, George Flanagan, and Ed Hillsman) for the definition of appropriate meteorological assumptions to use in the agent plume dispersion analysis, for the preparation of the generic fatality estimates and other demographic data bases, and for constructive criticism of the risk analysis work in progress.

- Office of the Program Executive Officer, Program Manager for Chemical Demilitarization (especially Tom Kartachak, Bob Perry, and Barbara Kuryk) for their constructive and timely review of this report and its drafts. Special thanks are due Tom Kartachak for his direct participation in the analysis and discussion of the data as presented in this report.

- H&R Technical Associates (especially Bill Rhyne et al. and George Malek, consultant) for their assistance in interpreting the transportation portion of the risk analysis data base for which H&R was the analyst (as subcontractor to GA Technologies).

- JBF Technical Associates (especially Jerry Fussel and Dave Campbell) for their assistance in refining and interpreting the analysis of plant operations (as subcontractor to GA Technologies).

- Battelle Columbus Laboratories (especially Barbara Bell and Ed Zamejc) for their contribution to the human factors and plant operations considerations in the risk analysis data base (as subcontractor to GA Technologies).

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1.0 INTRODUCTION

The U.S. Army's stockpile of chemical munitions is stored at eight sites throughout the continental United States. (See Figure 1.) The Army's Program Executive Officer - Program Manager for Chemical Demilitarization (PEO-PM Cml Demil) has the responsibility for disposing of the existing stockpile. This is a large scale effort that, by Congressional mandate, must be completed by September 1994. PEO-PM Cml Demil has developed the Chemical Stockpile Disposal Program (CSDP), which comprises several alternatives for carrying out the disposal effort (U.S. Army Toxic and Hazardous Materials Agency, 1986). This risk analysis is one of several studies intended to assist in the choice of a disposal alternative.

Chemical munitions are inherently dangerous, and the Army employs a sophisticated set of procedures and standards to minimize risks. There is always the chance, however, that some unexpected or unavoidable accident or event could occur that would expose a nearby civilian population to these toxic chemicals. Such events could occur even while the Army continues to store the chemical weapons stockpile. Now that the Army is committed to disposal of the stockpile, there is the need to examine the potential dangers due to a new set of possible accidents: those associated with the handling, transporting, and physical destruction of the munitions in the stockpile.

1.1 Purpose of The Risk Analysis

The major purpose of this risk analysis is to provide the Army with a consistent and quantitative comparison of the risks associated with each of the disposal alternatives. The relative risk to public safety of the alternatives has been evaluated on the basis of risk to the public (individuals outside the boundaries of the military installation) at proposed disposal sites and along potential transportation corridors.

This document reports the following risk analysis results:

- programmatic and site-specific risk to affected populations;
- factors affecting individual risk;
- major contributors to risk; and
- differences among alternatives.

An essential first step in risk analysis is the identification of potential accidents that contribute significantly to risk. Many of these

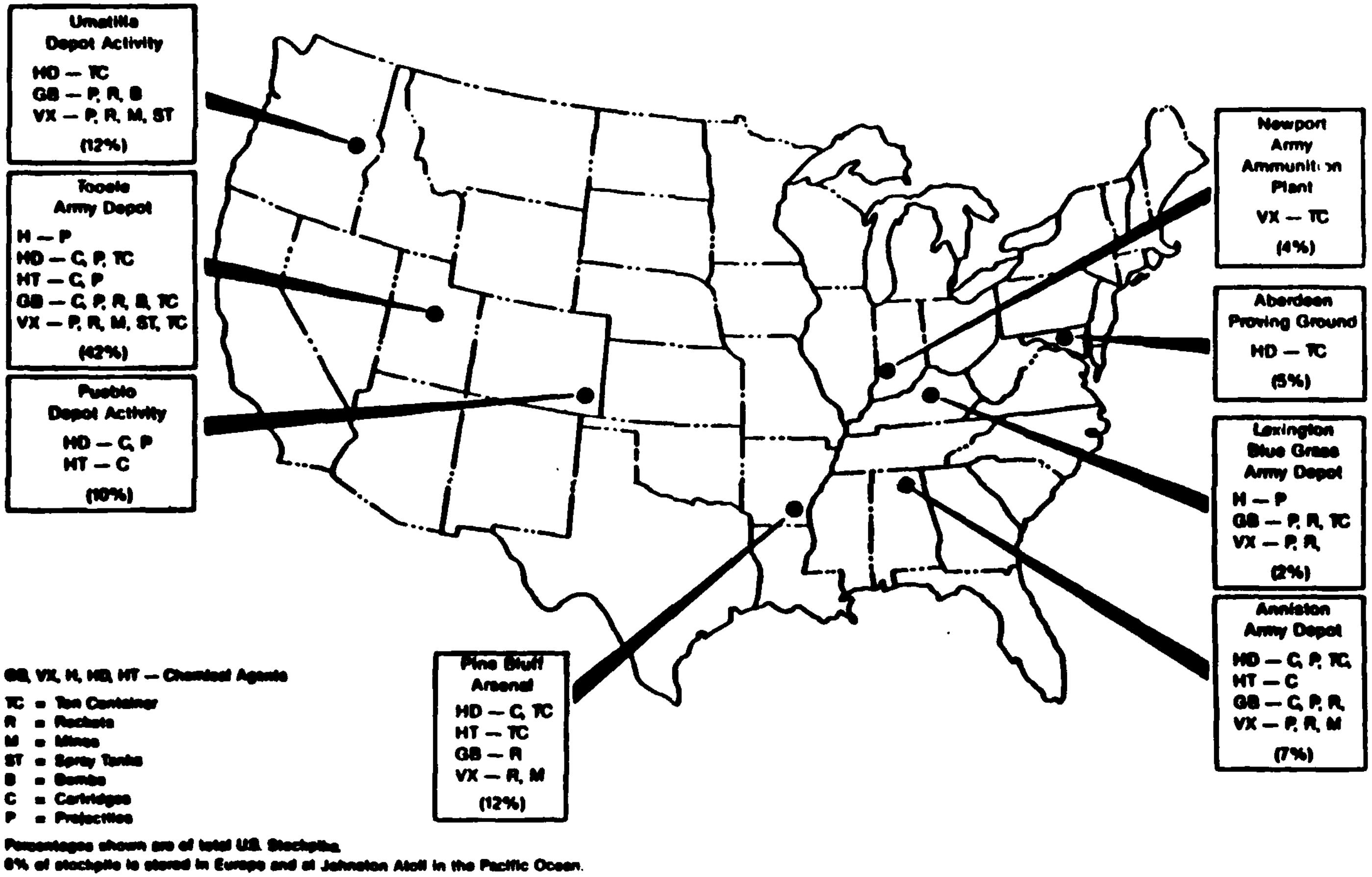


FIGURE 1

LOCATIONS OF CHEMICAL AGENTS AND MUNITIONS
IN THE UNITED STATES

potential accidents, once identified, can be prevented or mitigated through design and procedural changes. Because of this process of risk-reduction, the risk analysis itself plays an important role in the development of alternatives. That is, as the risk analysis results are acted upon to reduce main contributors to risks, overall risk may be reduced to very low levels. Eventually, all alternatives may become comparable on the basis of risk; the emphasis in comparing disposal alternatives then can shift away from relative risks to environmental, institutional, economic, and technical feasibility issues.

The risk analysis is intended to meet information needs of several audiences. The principal audiences are:

- Army decision-makers who must select a disposal alternative;
- local governments and community groups who need to understand and evaluate the potential impacts on their local populations;
- individuals who are concerned about their personal risk, given their locations with respect to storage sites, disposal sites, or transportation routes; and
- Army program managers responsible for implementing a disposal alternative, who must be aware of activities that have the potential for high risk to the public, and who must ensure that the CSDP is implemented safely.

Some of these audiences may be most concerned about community/societal risk -- that is, the total number of persons potentially affected by the program as a whole. Others may be concerned about identifying the major contributors to societal or community risk so they can do something about mitigating or managing it. Individuals are concerned about what the program means to them, personally, and may or may not be interested in community or societal risk.

Identifying the major sources of risk requires that the risk analysis be performed on an accident-specific basis. Data presented in Volumes 2 through 7 of this report support analysis at that level of detail. This document (Volume 1) presents more aggregated information on risk to society, using a set of complementary measures of risk.

Since risk analysis deals with potential future occurrences, uncertainty in the results is unavoidable. In addition, uncertainty in the risk analysis arises from gaps in data and in our understanding of the accident phenomena, which require that many assumptions be made in the

analysis. Estimates of uncertainty in the probability of accident occurrence have been developed, and are displayed with the risk estimates.

Despite uncertainties in the results, risk analysis remains the best available means for systematically identifying major sources of risk, quantifying safety concerns, and comparing the relative risk of the different alternatives. Subjective factors related to developing a sound safety philosophy (e.g., administrative controls) and to managing risks that are difficult to quantify (e.g., sabotage, procedural errors) are important also, and need to be considered along with the insights offered by quantitative risk analysis.

The data used in this risk analysis are of two broad types: historical data -- that is, data derived from records of a large number of actual events which are related to specific types of accidents, or events leading to them; and hypothesized data -- data derived from largely subjective modeling of assumed accident sequences with the aid of fault and event trees describing the process. (The use of fault and event trees is a standard procedure to investigate sequences of occurrences in a complex system.) Risk data for externally-caused accidents such as those due to aircraft crashes and destructive natural phenomena, as well as data related to off-site transportation (via rail freight, air, barge, etc.) can be drawn from historical data bases. Modeling data, based on analysis of hypothesized sequences involved in the accident scenarios, must be developed for those events which are unique to the handling and processing of chemical munitions, and for which there are very few historical data.

1.2 Risk Elements of The CSDP

To understand the ways in which the Chemical Stockpile Disposal Program (CSDP) might present risk to the public, one needs first to identify the major features of the CSDP, including:

- the disposal alternatives, including the "no-action" alternative (continued storage);
- the disposal activities (e.g., handling, transportation, plant operations) that make up the alternatives;
- the chemical agents themselves and the munition configurations in which they are stored; and
- the various accident initiators (e.g., human error, equipment failure, natural event) and accident types that could lead to agent release.

Each of these features is discussed below.

1.2.1 The Disposal Alternatives

For purposes of this risk assessment, the disposal alternatives are defined by where, not how, the destruction of the chemical stockpile takes place. The disposal technology assumed here for all alternatives is the "baseline" technology which consists primarily of mechanical disassembly of the munitions, draining of the chemical agent, destruction of the agent in liquid incinerators, incineration of "energetics" (propellants, bursters, etc.) in deactivation furnaces or kilns, and destruction of residual agent in metal parts and dunnage furnaces. The disposal alternatives are, therefore, distinguished by the logistics of munition movement and the location of the disposal activities. These alternatives can be summarized as follows:

- on-site disposal: all chemical agents are destroyed at the sites where they are now stored;

- regional disposal: munitions stored in the eastern region of the country are shipped by rail to Anniston Army Depot, Alabama, while those in the west are shipped to Tooele Army Depot, Utah;

- national disposal: all munitions in the Continental U.S. are shipped by rail to Tooele Army Depot for destruction; and

- partial relocation: on-site disposal at all sites except for relocation of the stockpile from selected sites:

  - the Aberdeen Proving Ground (MD) stockpile moved by air (C5 or C141 aircraft) to Tooele Army Depot or by water to Johnston Island;

  - the Lexington-Blue Grass Army Depot (KY) stockpile moved by air to Tooele Army Depot; and,

  - combinations of these two.

[Note: Of the partial relocation alternatives, all but the air mode using C141 aircraft are no longer under consideration by the Army; results for these abandoned alternatives are presented only as documentation of analysis performed prior to the Army's decision to drop them from further consideration].

The risk implications of the disposal alternatives are apparent in the potential for the redistribution and, it is expected, the reduction of overall risk. Movement of the stockpile from one site, in what could be a

densely populated region, to a second site, in what could be a sparsely populated region, might reduce the risk to the population around the first site, at the expense of added risk to people along the transportation corridor and around the second site. The magnitude of these risk differences is one of the questions answered by the risk analysis.

1.2.2 Disposal Activities

Each of these disposal alternatives comprises many activities. These range from the relatively simple activities associated with continuing to store the munitions, to the more complex activities associated with handling, shipping, or disassembly/destruction of the stockpile elements. Since these activities involve some contact with the chemical stockpile, they all could pose some risk to the public.

Figure 2 illustrates the major activities associated with each disposal alternative. Many of these activities are common to some or all of the disposal alternatives.

The "no-action" alternative, continued storage, involves the risks associated with storage in fixed sites (igloos, warehouses, or open fields). The major risk elements are relatively rare, external or natural catastrophic events, such as tornadoes and aircraft crashes; maintenance and surveillance activities for the stored stockpile also contribute to risk. Storage-related accidents are typically very low in their probability of occurrence, but very high in potential consequence, because of the large inventory of agent likely to be affected by any one event. In the continued storage alternative, all potential agent-releasing events (including leaks and maintenance-related handling accidents) are assumed to pose risk over an indefinite period -- taken for this analysis to be 25 years. No account has been taken in this analysis of the presumed risk of eventual disposal after a long period of continued storage.

The on-site disposal alternative involves risk posed by the following activities:

- handling activities, required to move the stockpile elements from their storage areas to on-site transportation containers, and from the transportation containers to the on-site disposal facility, and from one operation to another within the facility;

- on-site transport activities, moving the stockpile by truck from storage area to plant over on-site roads; and

- plant operations activities, including all steps required to disassemble, drain, and incinerate the chemical agents and munitions.

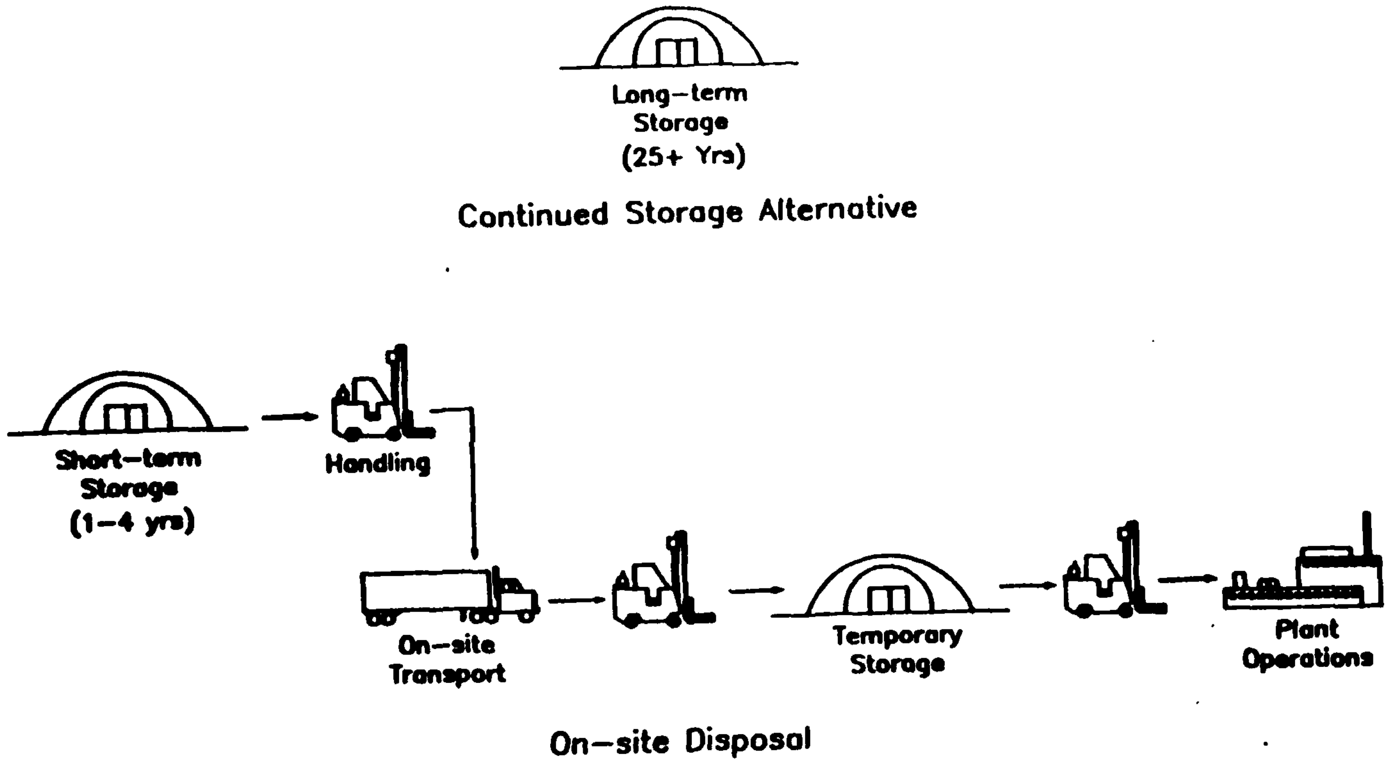
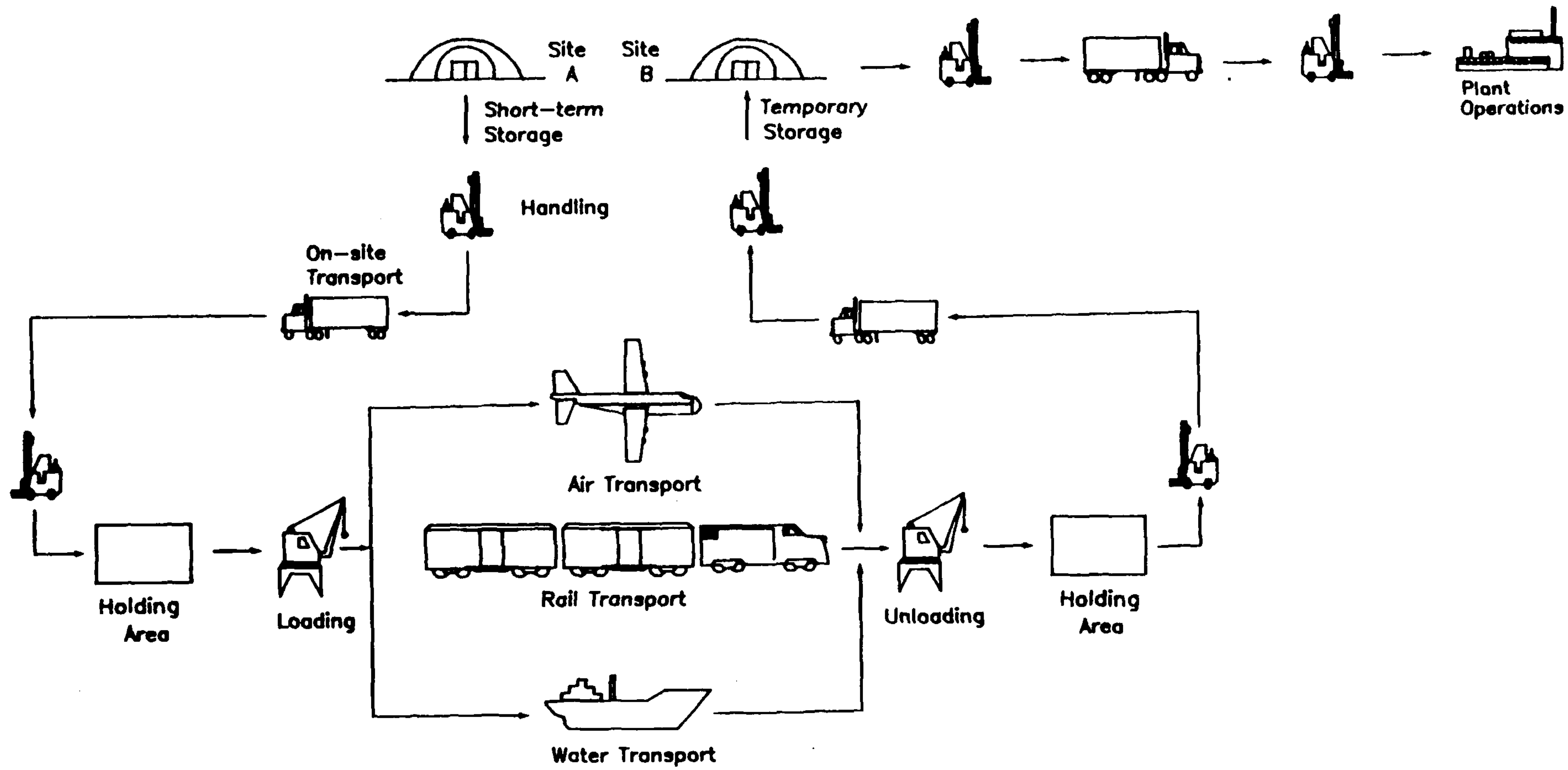


FIGURE 2

DISPOSAL ACTIVITIES INVOLVING SOME RISK



Disposal Alternatives Involving Transportation

FIGURE 2 (Concluded)

DISPOSAL ACTIVITIES INVOLVING SOME RISK

The national, regional, and partial relocation disposal alternatives introduce several different classes of activity posing some risk:

- additional handling activities, involving stockpile movement from storage to the packing/holding/loading areas (essentially the same risk as movement of the stockpile from storage to on-site disposal plant) for subsequent off-site transport, plus handling at the transportation container unloading/holding/unpacking areas and handling at the destination site (essentially a reversal of the activities at the sending site); and

- off-site (inter-site) transport activities, involving long distance transport by one of three modes, depending on which disposal alternative is being considered. (See S.C. Chu et al., 1987.)

For all the disposal alternatives, the risk of continued storage remains until the local stockpiles have been destroyed. However, this risk contribution is not included as an element of risk for the alternatives involving demilitarization of the stockpiles, because it is common to each of them, and would not help to differentiate among them.

In addition to comparing the risks due only to disposal activities, the risk analysis will demonstrate the very significant risk benefit resulting from any disposal alternative that eliminates the long-term risk associated with continued storage for 25 years (followed by the deferred risk of eventual disposal of the stockpile -- a risk element not considered in this risk analysis).

1.2.3 Agents and Munition Types

Each of the disposal alternatives involves the full range of chemical agent and munition types in the chemical stockpile. The characteristics of each are accounted for in the risk analysis. Risk associated with each of the agent types is different, since their physical and toxicological properties differ. Physical properties of greatest importance in estimating risk as a function of agent type include: vapor pressure (determines the rapidity with which spilled agent might evaporate); freezing point; and molecular weight. These and other physical properties, as well as toxicological characteristics, are encoded into the Army's D2PC computer model for chemical hazard prediction (C.G. Whitacre et al., 1987), which provides estimates of the downwind distance the chemical hazard might extend in a particular accident. Use of the model in this risk analysis is described in Appendix B of this report

The munition types included in the stockpile are described in Appendix A of this FPEIS. Major munition characteristics accounted for in the risk

analysis include: munition size and agent inventory; susceptibility to failure by puncture, crush, fire or impact; packing density; and presence of energetic materials (bursters, fuzes, and propellants).

1.2.4 Accident Types

Potential chemical accidents are defined in specific accident scenarios, which are sequences of possible events leading to a release of agent. Accident scenarios for which lethal exposures would not be experienced beyond 0.5 km from the storage and disposal sites under worst-case meteorological conditions have been excluded. Accident scenarios have been identified for major classes of accident causes, including natural phenomena (e.g., wind, flood, lightning), other external events (e.g., aircraft crash), equipment failures (e.g., pipe rupture, control system breakdown), and human error. The scenarios are presented in Section 4 of this appendix.

The threat of sabotage is being addressed elsewhere and is omitted from the accident scenario data base considered here.

1.3 Prior Studies

This risk analysis is founded on a number of prior hazard and risk analyses. Quantitative hazard analyses were performed on the proposed disposal of M55 rockets utilizing a technique known as hazard and operability analysis (HAZOP) (Arthur D. Little, 1985[a], 1985[b], 1985[c], 1985[d]). Qualitative analyses of the Johnston Atoll Chemical Agent Disposal System (JACADS), using a failure mode and effects analysis (FMEA) method were carried out by the R.M. Parsons Company (1983, 1985).

Deductive system logic models, such as fault trees, were used to assess the probability of agent release in off-site transportation accidents (Rhyne, 1985[a], 1985[b]). Rhyne's study incorporated the transportation accident data base prepared by Sandia National Laboratories (Clark et al., 1976). An analysis of disposal of M55 rockets by Science Applications International Corporation (1985) focused on the storage, handling and on-site transportation of chemical munitions, using both the event tree and fault tree methodologies.

For the draft programmatic environmental impact statement (DPEIS) for the CSDP (U.S. Army Program Manager for Chemical Demilitarization, 1986), the MITRE Corporation outlined an approach for using the risk data prepared in support of the M55 rocket disposal program as the basis of an accident scenario data base applicable to the entire stockpile (Fraize et al., 1987). MITRE then identified gaps in the accident scenario data base

(subsequently addressed by GA Technologies), and proceeded to develop a framework for analyzing the risk associated with this resulting accident scenario data base and identifying representative worst case accidents for the CSDP/EIS. This framework and the preliminary accident scenario data base, as updated and completed by GA Technologies, was used to prepare the risk analysis supporting the DPEIS (U.S. Army Program Manager for Chemical Demilitarization, 1986).

1.4 Data Sources for This Analysis

With the studies listed above as the starting point, GA Technologies (GA Technologies, 1987a, 1987b, 1987c), with technical assistance from H&R Technical Associates, JBF Associates, and Battelle-Columbus Laboratories, conducted a comprehensive assessment of accident probabilities for all munition types. Event and fault tree analyses, together with information on mechanical and thermal failure threshold conditions for each munition type, were used to estimate the probability of agent release in each of nearly 3000 potential accidents, and the amount of agent that could be released.

Downwind dispersion of lethal plumes was determined by a method incorporated in the D2PC plume dispersion model developed by the Army (Whitacre et al., 1987). Demographic data and potential fatality estimates for generic accidents (defined by lethal plume length and meteorological conditions) for all sites and transportation corridors were provided by Oak Ridge National Laboratory. An overview of the approach used for assimilating the probability and consequence information is depicted in Figure 3. The ovals on the left edge of Figure 3 represent the four major data inputs to the risk analysis:

- probability data (from GA Technologies)
- agent release data (from GA Technolcgies)
- meteorological data (from ORNL)
- fatality data (from ORNL)

These four major data sets are then integrated in ways that represent the disposal alternatives defined by the Army to yield measures of risk. More detail on the risk data integration process is presented in Appendices A and B of this report.

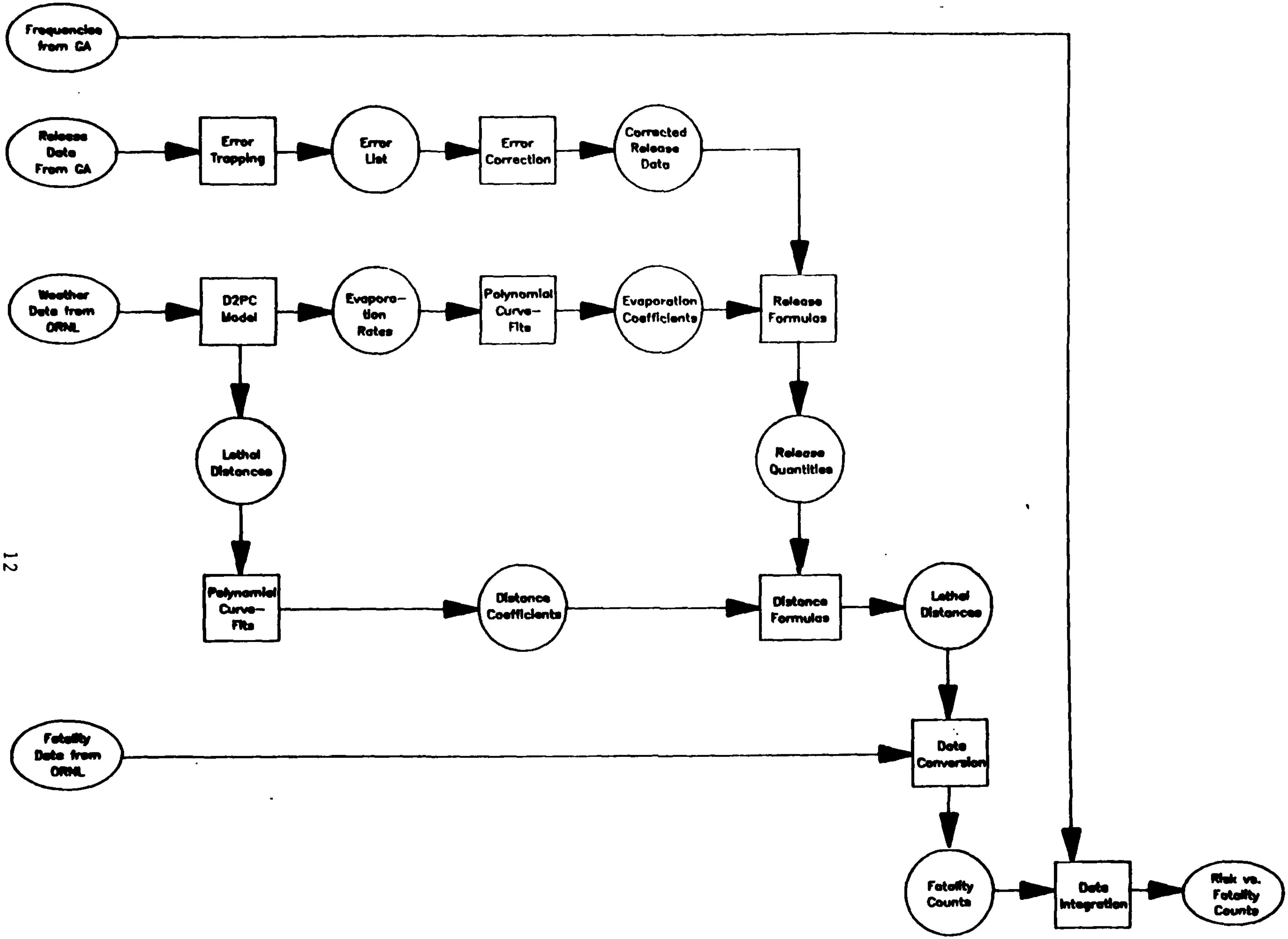


FIGURE 3

SCHEMATIC DIAGRAM OF RISK DATA PROCESSING

1.5 Organization of this Report

This report consists of seven volumes, containing the following information:

- Volume 1: Analysis (this document, UNCLASSIFIED) contains a description of the methodology used in the risk analysis and a presentation and discussion of the results;

- Volume 2: Consequence Data (UNCLASSIFIED) presents the results of all computations of potential consequence (plume lengths, fatality rates by distance, and potential fatalities for two meteorological conditions and, for site-specific fatality estimates, average and highest density population distributions;

- Volume 3: Risk Analysis Summary Tables and Individual Risk Data (SECRET) contains tables summarizing all the risk analysis results by storage/disposal site, locale (originating site, transportation corridor, or destination site for transported stockpiles), and disposal alternative; individual risk curves for each site and all applicable disposal alternatives are also provided.

- Volumes 4 - 7: Detailed Risk Data (SECRET) contain the results of all risk computations on an accident-specific basis, by site, locale, disposal alternative, and accident activity category:

    - Volume 4: Originating Sites

    - Volume 5: Transportation Corridors

    - Volume 6: Destination Sites

    - Volume 7: Selected Sorts to Support Interpretation of the Risk Analysis Pictograms.

2.0 METHODOLOGY OF THE RISK ANALYSIS

The purpose of this section is to present basic principles involved in estimating risk to the public, and to show how these principles have been applied to the Chemical Stockpile Disposal Program (CSDP).

2.1 Introduction to Risk Assessment Concepts

Risk is a measure of the potential for exposure to unwanted events or consequences (e.g., injuries or fatalities). Any danger to the public associated with the proposed Chemical Stockpile Disposal Program may be described in terms of risk. For purposes of this study, risk is considered to be that due only to accidental release of, and potential public exposure to, chemical agent. Only accidents that could result in a release of agent sufficient to expose the public to potentially lethal doses are included. For purposes of this study, the term "public" excludes persons within the boundaries of the military installations.

2.1.1 Risk Descriptors: Probability and Consequence

The risk associated with any activity (e.g., living near a geologic fault, driving a car, riding a roller-coaster, or living under an airplane flight path) may be described as the product of two quantities: the probability of the unwanted event occurring and the consequence to an individual or the public, if the event does occur.

The probability of a potential accident is a quantitative statement of the "odds" of that accident occurring, given many repetitions of the activity or condition that can lead to the accident. For instance, analysis of the accident and all of the separate events leading up to it might show that the odds of the accident occurring at some time during the CSDP might be 1 in 200,000; we can express the probability of that event occurring in just that way -- 1 in 200,000 -- or in the following equivalent ways: 0.000005; 1/200,000; or, in scientific notation, 5×10^{-6}. For this analysis, the probability of an accident is expressed as the likelihood (or "odds") of its occurring once during the stockpile disposal program. The only exception is for long-term storage accidents where probability has been expressed as the likelihood of occurrence during a 25-year period (the assumed duration of the "no-action" alternative).

The consequence of a potential accident can be expressed in several ways, depending on the intended use of the results. For the purposes of the CSDP risk analysis, there are two principal measures of the consequence of any given accident:

- size of the lethal plume produced by the accident. Size of the lethal plume is defined as the distance to the downwind location where the "exposure" (the product of agent concentration and time) is equal to the estimated minimum lethal value. This distance is also referred to as the "no-deaths" hazard distance. Plume size, or downwind hazard distance, is dependent on the agent type (physical characteristics), agent quantity released and the meteorological conditions governing the atmospheric dispersion of the agent.

- potential fatalities per event. This measure is the most direct indicator of potential accident consequences to the population. Estimation of potential fatalities requires knowledge of the source term (quantity and mode of agent release), the atmospheric dispersion mechanism (specified by local meteorological conditions), the population distribution (by distance and direction), and the estimated human response to chemical agent exposure.

The present risk analysis is limited to airborne release of agent. Other modes for dispersion of released agent, such as through ground water or surface water, are beyond the scope of this analysis. Only acute and lethal toxicity are considered in the analysis; chronic and sub-lethal effects are not evaluated.

2.1.2 Two Perspectives on Risk

Risk can be viewed from two basic perspectives:

- Risk to an individual at a specified location; and

- Risk to the affected populations.

In the first case, risk to an individual is the probability that he or she will be harmed while at a fixed location. Risk to the affected population (the expected number of individuals who might be adversely affected by the event) may be more useful to a decision-maker who needs to assess total effects on the public.

An individual tends to view risk in very personal terms, such as the probability that an unwanted event will occur to him or to his family. Many risky activities or situations to which an individual is exposed are voluntary (e.g., a canoe ride) and their risk is accepted in return for the benefit the activity brings. Others (e.g., being struck by lightning) are "acts of God or nature" and the associated risk is generally accepted as a part of living. Still others (e.g., living near a nuclear power plant or along a rail route that carries hazardous chemicals) are viewed as

involuntary, the result of man-made intrusions, and often are less willingly accepted. In this risk analysis, we are dealing with a man-made activity that the public may view as an imposed or involuntary risk. Risk comparable in character (not necessarily magnitude) to that potentially imposed by the CSDP might be that associated with living next to a chemical plant processing hazardous chemicals or living along a transportation route carrying such materials.

Community or societal risk is, in effect, the aggregate of individual risk to which all members of the local population are exposed. Thus, individual risk is independent of the number of individuals at risk; community or societal risk is not.

2.2 Application of Risk Concepts to the CSDP

2.2.1 Computation of Individual Risk (General Case)

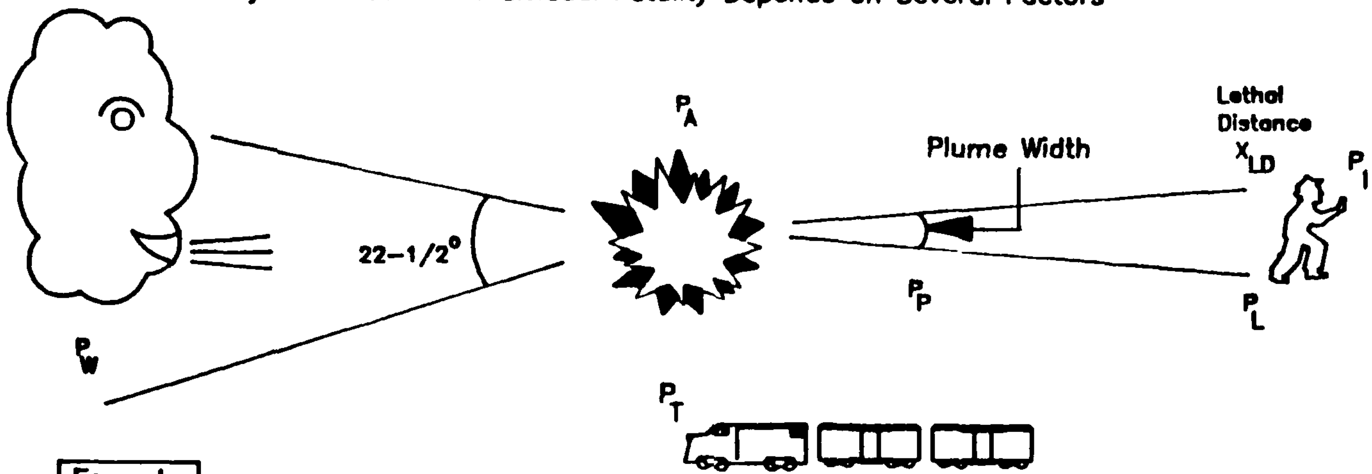
The risk to an individual is calculated by multiplying together the probabilities of each of the circumstances necessary to produce a fatality. This combined probability of occurrence is multiplied by the consequence to determine risk; in the individual case, consequence is always equal to 1 (the death of the individual), and so does not affect the risk value we calculate. Figure 4 illustrates the major factors affecting the risk to an individual posed by a potential release of chemical agent; these factors, described in detail in Appendices A and B, are:

- the probability that an accidental release will occur;
- the probability (along transportation corridors only) that a transport vehicle will be in the vicinity of the individual when the accident occurs;
- the probability of being downwind of the release;
- the probability of being within the plume width;
- the probability that an individual within a given lethality zone of the plume will die.

For the case of individual risk along a transportation corridor, the analysis is based on determining the route length over which an accident can occur and still affect an individual at a given location. As shown in Appendices A and B, this is equivalent to basing individual risk on exposure time. Basically, the analysis computes average individual risk along the transportation corridor, based on average distances, speeds, and exposure times along the route.

Concept:

The Probability of a Potential Individual Fatality Depends on Several Factors



Formula:

$P_I = P_W \times P_A \times P_T \times P_P \times P_L$ Where:

P_I = Probability of an Individual Fatality
P_W = Probability of Wind Directed from an Appropriate Sector
P_A = Probability of an Accidental Release of Agent
P_T = Probability of a Train being Present (as applicable)
P_P = Probability of an Individual Being within the Plume Width
P_L = Probability of a Potential Fatality for an Individual within the Plume

Typical Data are:

$P_I = 0.06 \times P_A \times 1.0 \times 0.3 \times 0.2 = 0.004 \times P_A$

FIGURE 4

ILLUSTRATION OF INDIVIDUAL RISK

Whether along a transportation route or near a fixed site, the total risk to an individual is the sum of the individual risks posed by each identified accident scenario that could happen at the individual's location (either along a corridor or near a site).

2.2.2 Risk to the Population (Community/Societal Risk)

To estimate the risk to the general population, the factors defining risk to an individual, discussed above (section 2.2.1), must be applied to the total number of individuals at risk. Risk to the public was calculated for each accident by overlaying the lethal plume (under "most-likely" weather conditions) associated with the accident on a map of the residential population about the site or adjacent to a transportation corridor and estimating the number of potential fatalities within the plume. Next, expected fatalities from each accident were computed as the product of potential fatalities and the probability of the accident occurring. The total population risk was then determined by summing expected fatalities for all applicable accidents.

This concept is illustrated by Figure 5. The concentric arcs in the figure represent hazard distance zones from the potential accident site. For example, the distance zones used in this analysis are the following:

>0.0 - 0.1 km	> 2 - 5 km
>0.1 - 0.2 km	> 5 - 10 km
>0.2 - 0.5 km	> 10 - 20 km
>0.5 - 1.0 km	> 20 - 50 km
>1 - 2 km	> 50 - 100 km

An accident having a "no-deaths" plume length of 12 km is assumed to result in a fatality count for the zone which is 10 - 20 km from the accident site. If an accident causes a plume that reaches into the 10 - 20 km population zone, then all those in the inner population rings, closer to the agent source, are at even more risk since the dosages become higher as one approaches the accident site. Similarly, within a given distance zone, individuals will be affected not only by those scenarios for which the plume just reaches their zone, but also those accidents of greater magnitude for which the plume reaches into the outer zones. While plume lengths exceeding 100 km may be estimated in the D2PC model for the worst of the potential accidents, a correction has been made to exclude fatalities that would occur farther than 100 km from the potential accident location.

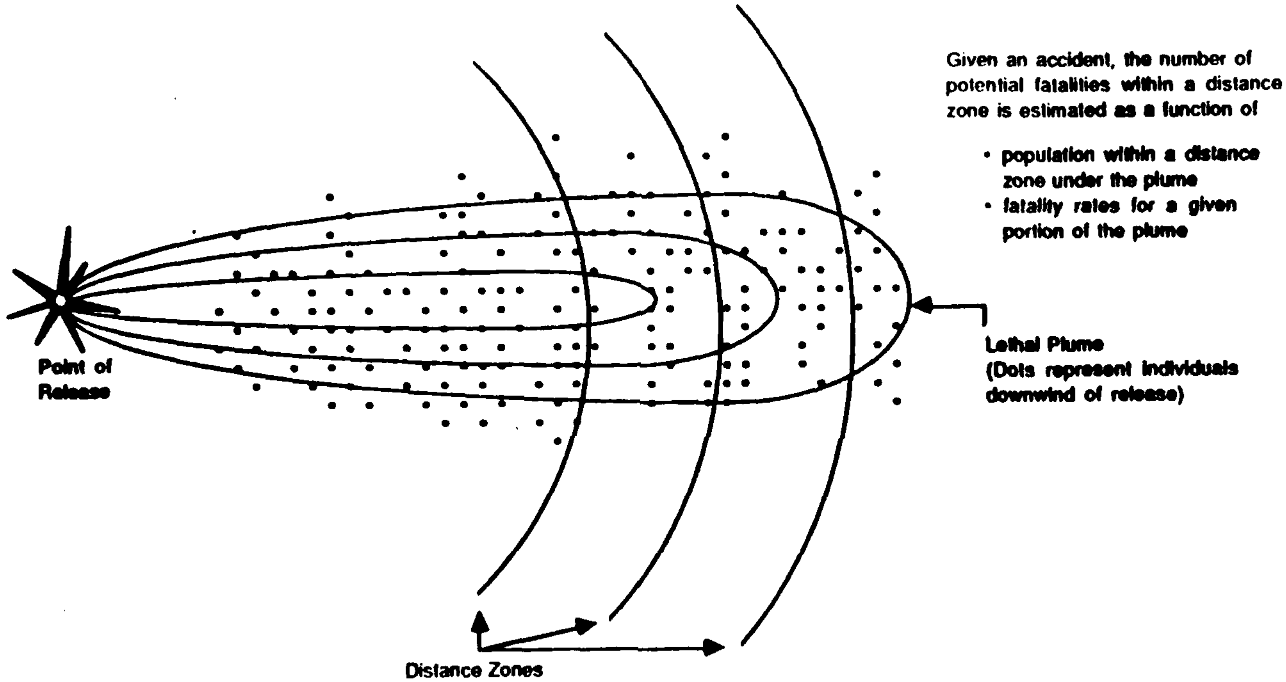


FIGURE 5

ILLUSTRATION OF POPULATION RISK

2.3 Principal Measures of Risk

To compare the public risks of the disposal alternatives, the following measures, each of which provides a different perspective on program risk, are used:

- **maximum individual risk**, equal to the probability of an individual's death if he/she spent the entire duration of the CSDP at the site boundary (assumed to be 0.5 km from the on-site disposal/storage operations) or as close as 0.1 km to the centerline of a transportation corridor. This indicator is dependent only on the mix of potential accidents that could happen at the individual's location; it is independent of population density (the number of individuals who could be so maximally exposed;

- **maximum lethal distance**, equal to the maximum downwind length ('no-deaths' exposure level) of the plume from the worst of all identified potential accidents under worst-case weather conditions at a specific location. Conversely, it is also the minimum distance an individual could be from a given site or transportation corridor and have no risk of lethal exposure during the CSDP;

- **maximum total time at risk**, representing the maximum length of time an individual could be at risk at a fixed location near a site or along a transportation corridor. For those living within a radius equal to or less than the maximum lethal hazard distance, the time at risk is the total time during which stockpile disposal activities will take place at that site, regardless of where the individual is located. For those individuals along the transportation corridors, the time depends on the distance from the rail line or air corridor; the maximum time is assumed to occur if the individual is located at a 0.1 km distance from the rail track or centerline of the air corridor. These persons are exposed to a hazard only when a train or aircraft is in the vicinity (defined as the maximum lethal hazard distance in either direction) of them. This time is summed for each agent-bearing train or aircraft that would pass by in each alternative. Since maximum lethal hazard distance is used in this determination, the worst case meteorological conditions apply;

- **probability of one or more fatalities**, a public risk indicator equal to the chance that there will be at least one fatality at a given site or for the nation as a whole during the CSDP. This measure is calculated by summing the probabilities of all accidents that could cause one or more fatalities. Included in this sum are all accidents for which the potential fatality estimate, based on

assuming uniform population densities, is less than unity. (This means that that accident is expected to cause a fatality for only a fraction of the times it occurs; for the remaining fraction of occurrences, that event would not cause a fatality. For such accidents, the probability of occurrence is reduced so that only the fraction of events expected to cause a fatality are counted). [To illustrate: On the basis of average population density and lethality rate variations within the chemical agent plume, an accident could have a potential fatality value of, say, 0.2 and a probability of occurring estimated at 10^{-4}; the potential fatality value of 0.2 means that 20%, or 1 out of every 5 occurrences of the event in question could cause a fatality. Those 4 occurrences that cause, on average, no fatality are not counted and the accident is, in effect, redefined to be the 1-in-5 event that leads to a fatality -- having a correspondingly reduced probability, equal to the fraction of fatal accidents times the probability of all occurrences, or 0.2×10^{-4}.];

- **maximum number of fatalities**, equal to the maximum consequence of all accidents at a site or for the nation. This risk measure is based on worst-case weather conditions, actual population densities (1980 census data, as analyzed by Oak Ridge National Laboratories), and worst possible wind direction (i.e., plume striking the highest number of people without any allowance for preventive/emergency response measures);

- **expected fatalities**, equal to the sum of the risk contribution of all accidents at a site or for the nation, where risk for each accident is the potential fatality count (if the accident were to occur) multiplied by the probability of the accident occurring. Note that expected fatalities is proportional to the probability of a fatality-causing event occurring, and will nearly always be a small number -- well less than unity. For example, an accident with a <u>potential</u> fatality estimate of 12 and a probability of 10^{-6} (odds of 1 in a million of occurring during the CSDP) would have an <u>expected</u> fatality value of 12×10^{-6}. At the programmatic level, the expected fatalities value is the sum of the expected fatality contribution of several hundreds of potential events and might lie somewhere in the range of 10^{-3}, or 0.001. This typical value can be interpreted in the following way: The program can be expected to cause, on average, one fatality every 1000 times the program is executed; since the program consists of many events which could cause multiple fatalities, a more typical interpretation would be made up of several parts, such as: one fatality every 10,000 programs (expected fatality contribution of 1/10,000 = 0.0001) <u>plus</u> a 10-fatality event every 25,000 programs (contribution of 10/25,000 = 0.0004) <u>plus</u> a 100-fatality event every 200,000

programs (contributing 100/200,000 = 0.0005), for a total expected fatality value of 0.001; and

- person-years-at-risk, equal to the population living within all zones (defined in Section 2.2.2) that could experience potentially lethal agent exposure multiplied by the time period over which that worst-case event could take place (typically, the duration of disposal operations at fixed sites or the time during which transport vehicles might be within lethal plume reach of population groups along the corridors). This measure does not account for the fact that individuals within the affected population groups who are farther from the potential accident site are at lower risk of suffering ill effects of exposure; all affected individuals are counted if they have any risk at all. (This measure is discussed in more detail in Section 3.3.3.2.).

The first three risk measures are indicators of risk to the individual. The next three apply to community/societal (population-based) risk, with each measure representing one of the three major features of the cumulative risk curve: vertical scale intercept (probability); horizontal scale intercept (maximum fatalities -- worst case value); and area under the risk curve (expected fatalities) [**Note**: Equating **expected fatalities** with the area under the risk curve applies only if the curve were plotted using linear scales -- equal increments for equal changes in the value of the plotted parameters -- instead of the logarithmic scales -- equal increments for each 10-fold multiple of the value of the plotted parameters -- necessitated by the very wide range of the risk data.] Person-years-at-risk is also a community/societal risk measure.

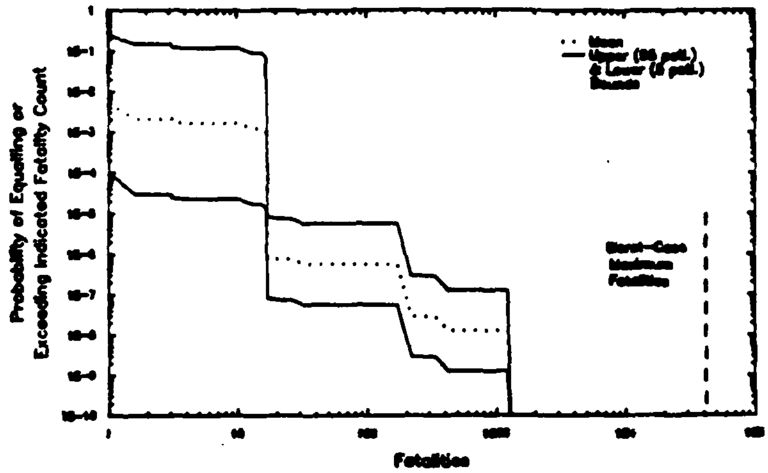
2.4 Methods for Portraying Risk

Estimates of risk to the population can be displayed in a variety of ways. Those used in this report are illustrated by Figure 6:

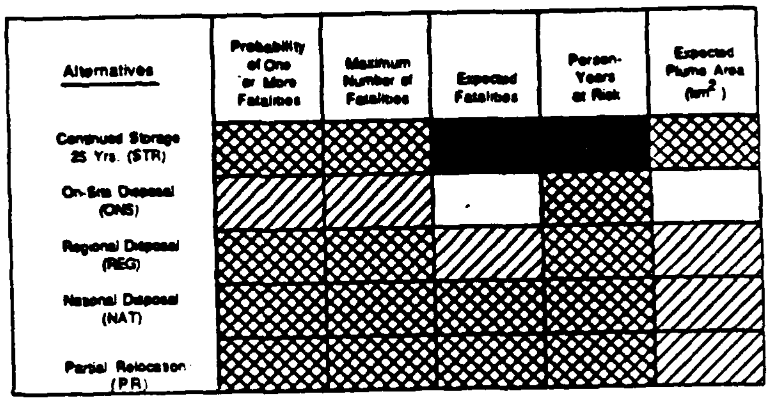
Item A. Risk curves, which portray, for the full set of applicable accident scenarios:

- the probability of exceeding a given number of potential fatalities per event (vertical axis), against
- the potential fatalities per event (horizontal axis);
- the upper and lower bound estimates, as well as the mean (average) value, reflecting the uncertainty in the probability component of the risk curve -- the uncertainty range defining the 90% confidence limits; and

A. RISK CURVE



B. RISK PICTOGRAM



C. EXPECTED FATALITIES PLOT

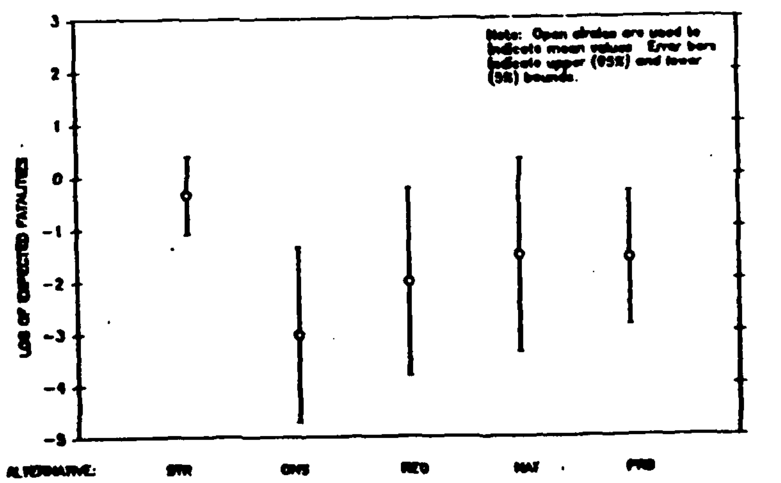


FIGURE 6

PORTRAYAL OF PUBLIC RISK (3 EXAMPLES)

- the maximum potential fatalities, assuming worst-case meteorology, distributed population, and worst possible wind direction, shown as a dashed vertical line.

Risk curves depict the difference between alternatives dominated by high-probability/low-consequence accidents and those dominated by `ow-probability/high-consequence accidents.

An illustration of a cumulative risk curve, showing a number of sources of community/societal risk, is presented as Figure 7. Figure 7 serves not only to indicate historical precedent for use of cumulative risk curves but will also enable the reader to compare the results of the CSDP risk analysis with the risk reported for other types of societal risk.

Item B. Risk pictograms, which display:

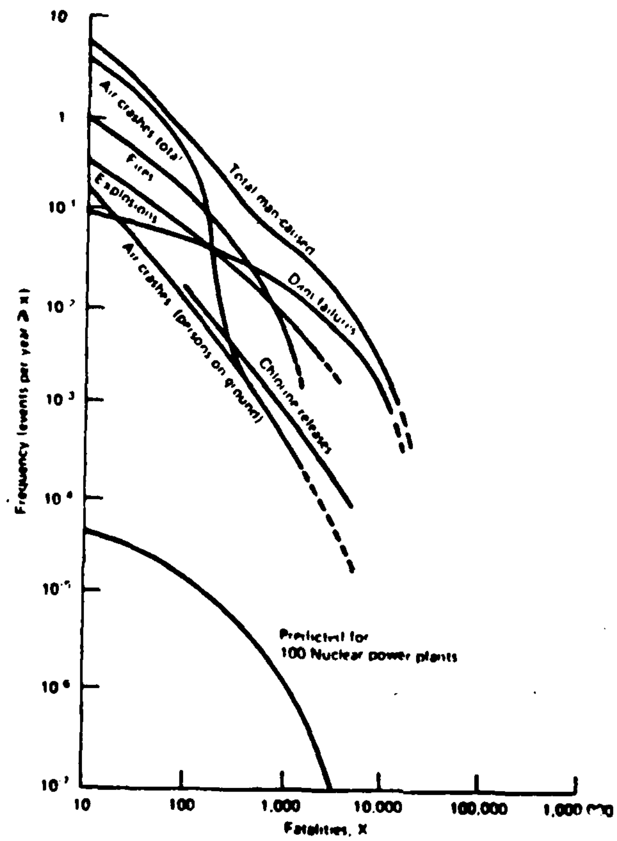
- a pictorial indicator (the darkness of the shading) of the relative magnitude of each of the measures of risk chosen for this analysis;

- a key to the numerical range represented by each of the shading values; and

- an array of data allowing comparison of risk at all sites for a given disposal alternative or, alternatively, comparison among alternatives for a given site (both approaches are used in this report).

Risk pictograms provide a visual impression of the relative magnitude of public risk for all combinations of alternatives and locations.

Item C. Expected fatalities plots, showing mean estimated values of expected fatalities, with uncertainty bands. The expected fatalities value is defined as the sum of the risk (probability times potential fatalities) for all applicable accidents. While this measure of risk is convenient and consistent, permitting the summing and disaggregation of the contributions to CSDP risk, it provides the least information of any of the risk measures. For example, it does not clearly show the relative contributions of low consequence/high probability accidents and high consequence/low probability accidents, which is often of great interest to the public. As illustrated in Figure 4, expected fatality data are presented in this report with error bars indicating the estimated uncertainty in the calculated value. The extremes of the error bars represent the 90% confidence limits -- that is, there is only a 10% probability that the actual expected fatalities value would fall outside the indicated range.



Comparisons of risks for fatalities. [*From Reactor Safety Study*, WASH-1400 (*October 1975*).]

FIGURE 7

EXAMPLE USE OF RISK CURVES

3.0 PRESENTATION OF RESULTS

The detailed results of the risk analysis, describing the consequences, probability, and all relevant risk parameters for each identified accident for all locations and disposal alternatives, are presented in Volumes 2 through 7 of this report. In this section, we will present a summary of that risk data and will discuss the significance of the results from both programmatic (all locations combined, for each disposal alternative) and location-specific considerations.

Unless stated otherwise, the term **risk** will refer to **expected fatalities**, while **plume length** will mean the **'no-deaths' hazard distance under most-likely meteorological conditions**.

3.1 Overview of Risk Data

The risk data contained in Volumes 2 through 7 (all but Volumes 1 and 2 are classified) of this report include, for each identified potential accident, all the information necessary to determine the major risk parameters identified in section 2.2.4: **maximum individual risk**; **maximum lethal distance**; **probability of one or more fatalities**; **maximum number of fatalities**; **expected fatalities**; and, **person-years-at-risk** (derived from estimated **time-at-risk**). **Expected plume area** is also presented as a measure of ecological risk. Each of these parameters is relevant only to a set of potential accidents which could take place at a specified location (fixed site or along a transportation corridor) for a given site-specific stockpile (identified by its originating site) and a given disposal alternative. Thus, throughout this section, we will refer to the following three descriptors of the accident scenario set of interest:

- **Disposal Alternative** (see below)
- **Site-Stockpile** (see below)
- **Location/Locale of Risk** as defined by:
  - OS = Originating Site
  - DS = Destination Site
  - TC = Transportation Corridor

For programmatic risk portrayal, all three locales are combined. For site- or location-specific risk portrayal, the risk at only one locale is shown.

3.1.1 Disposal Alternatives and Site-Stockpiles Considered

The eight site-stockpiles considered in this analysis are identified in Figure 1. The codes used throughout this analysis to signify particular sites are tabulated below:

G - APG - Aberdeen Proving Ground, MD
L - LBAD - Lexington-Blue Grass Army Depot, KY
B - PBA - Pine Bluff Arsenal, AR
N - NAAP - Newport Army Ammunition Plant, IN
P - PUDA - Pueblo Depot Activity, CO
U - UMDA - Umatilla Depot Activity, OR
A - ANAD - Anniston Army Depot, AL
T - TEAD - Tooele Army Depot, UT

Eight disposal alternatives were analyzed. Their one-line descriptions, and the codes used to represent them in the analysis and in the presentation of the results are given below:

S - STR - Continued Storage (for 25 years)
O - ONS - On-Site Disposal
R - REG - Regional Disposal (via rail)
N - NAT - National Disposal (via rail)
A - PRA - Partial Relocation -- On-Site Disposal, except APG & LBAD Stockpiles to TEAD via air (C5 aircraft)
B - PRB - Partial Relocation -- On-Site Disposal, except APG & LBAD Stockpiles to TEAD via air (C141 aircraft)
C - PRC - Partial Relocation -- On-Site Disposal, except APG Stockpile to Johnston Island (JI) via water and LBAD Stockpile to TEAD via air (C141 aircraft)
W - PRW - Partial Relocation -- On-Site Disposal except APG Stockpile to Johnston Island (JI) via water

Of these eight alternatives, five were selected by the Army for more detailed analysis that included a study of the impacts of mitigation measures (discussed below in section 3.1.2) and presentation and analysis in the Final Programmatic Environmental Impact Statement (FPEIS) of the CSDP. The selected five alternatives (to be referred to elsewhere in this report as the "five FPEIS alternatives") are: continued storage (STR), on-site disposal (ONS), regional disposal (REG), national disposal (NAT), and partial relocation by air mode (C141) for the APG and LBAD stockpiles only (PRB -- also referenced by the code PR in some sections of this appendix and in the body of the FPEIS).

3.1.2 Treatment of Mitigation

The accident scenario data base was analyzed for the unmitigated case plus two levels of mitigation, the details for which are described in an Army report (PEO-PM Cml Demil, 1987[a]). The three levels are:

1. Unmitigated. The accident scenarios as defined and characterized by GA Technologies (1987[a,b,c]) were used.

2. Mitigated, Revision 1. The unmitigated accident scenario data base was modified by the following measures which are expected to significantly reduce the effects of high risk scenarios identified by analysis of the unmitigated data base; expected benefits for each mitigation measure are also indicated:

   - Reduce time required to clean up spill to under 15 minutes by applying foam or other material to a spill occurring during handling or on-site transportation.

     Expected Benefit: Spill duration reduced by 75 percent (handling accidents) or 87 percent (on-site transportation accidents).

   - Use battery-powered lifting devices for handling.

     Expected Benefit: 99 percent reduction in probability.

   - Install blunt bumpers on lift truck tines.

     Expected Benefit: 65 percent reduction in probability.

   - Use improved mobile device to control vehicle fire during on-site transportation.

     Expected Benefit: less than 1 percent reduction in probability.

   - Install seismic-actuated gas cut-off valves and category 3 breakers in the munition demilitarization building (MDB).

     Expected Benefit: Probabilities for earthquake-caused scenarios, plant operations accidents PO___ 26 and PO___ 29 (see Appendices A and C for descriptions of accident scenarios), are reduced by 80 to 88 percent, depending on the site. Probability of plant operations accident PO___ 33, also an earthquake scenario, is reduced by 90 percent.

- Install a metal shield over the conveyor at the explosive containment vestibule (ECV).

  Expected Benefit: 99 percent reduction in probability for the munition detonation scenarios, plant operations accidents PO___ 46 and PO___ 47.

- Implement changes in the unpack area (UPA) to prevent mines and rockets from being inadvertently conveyed to the dunnage furnace (DUN). All measures necessary to reduce by a factor of 100 the probability of a munition reaching the DUN will be implemented. The measures under consideration are the following:

  - interlock mine and explosive counters at the mine glovebox with the dunnage conveyor using redundant sensors and positive shut-off.

  - independently interlock a drum weighing device at the mine glovebox to the dunnage conveyor.

  - interlock a metal detector with the DUN airlock to preclude transporting a rocket to the DUN.

  - inspect the dunnage for munitions.

  - replace manual handling of rockets by using a mechanical hoist to lift rockets from the pallet.

  Expected Benefit: 99 percent reduction in probability for the dunnage furnace accident scenario, PO___ 52.

- Transport mustard ton containers in frozen state.

  Expected Benefit: 94 percent reduction in amount evaporated for rail transport accidents involving a spill of mustard agent; 85 percent reduction for the corresponding air transport accidents. [A detailed description of the benefits of low temperature transport of mustard agent may be found in an Army report (PEO-PM Cml Demil, 1987[b])]

- De-energize warehouse electrical system using seismically-actuated circuit breakers or disconnected electrical leads.

  Expected Benefit: 98 percent reduction in probability of a warehouse fire caused by an earthquake.

3. Mitigated, Revision 2. The accident scenario data base, as mitigated by the measures described above (mitigation, Revision 1), was further mitigated by the following additional measure:

- Restrict air space at all of the sites and eliminate military helicopter flights.

  Expected Benefit: 100 percent reduction in probability of air crash accidents of military helicopters, and 92 percent reduction in all other crashes.

3.1.3 Treatment of Uncertainty

Uncertainties in risk estimation arise due to many causes, including the inadequacy of data, inaccuracies in modeling, and the incomplete identification and understanding of accident phenomena. The basis for estimating uncertainties when summing probabilities or probability-weighted data with known individual uncertainties is described in Appendix B of this report.

The analysis of accident scenarios carried out by GA Technologies provides an error factor for each accident probability "point estimate". This error factor was used to characterize the uncertainty inherent in each estimate. The contribution to risk uncertainty of consequence estimation (for example, in estimating potential public fatalities as a result of an agent release) is represented separately (though incompletely) by considering most likely and worst case meteorological conditions. However, since worst case conditions occur relatively rarely and have greater consequences, they may have little effect on a risk curve.

In this report, uncertainty is portrayed on the risk curves and on the expected fatality plots where upper and lower uncertainty bounds (at the 95 percent and 5 percent levels) are indicated.

3.1.4 Description of Data

Risk data are summarized in several forms. In section 3.2, risk data for the programmatic level (no location-specific information) are presented for the unmitigated case plus two levels of mitigation in three forms:

- semi-quantitative, graphical/pictorial comparisons of major risk parameters in 'pictograms'.
- graphical comparisons of expected fatality estimates, with upper and lower uncertainty bounds; and

- cumulative risk curves, with upper and lower uncertainty bounds.

In section 3.3, location-specific risk data are presented, but in 'pictogram' form; location-specific risk curves are not presented because they could reveal classified information.

3.2 Programmatic Risk of Alternatives

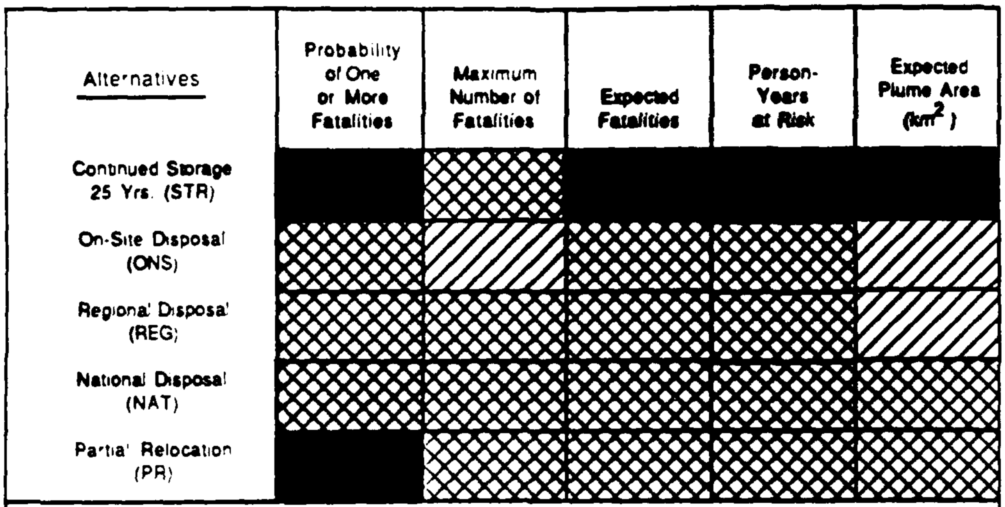
3.2.1 General Comparison

Figures 8 through 10 display in pictogram format (using matrix elements shaded according to four numerical equivalence ranges) the four major risk measures plus a fifth measure -- the expected value of plume area (provided for the purpose of evaluating ecological risk in the FPEIS) for the five FPEIS disposal alternatives. The shadings are chosen so that higher risk is connoted by darker shading. The numerical ranges were chosen so that the full range of values for all alternatives could be displayed and readily differentiated. The shading assigned to any entry in the pictograms is strictly defined by the mean value of the risk measure relative to the numerical boundaries of the ranges. Differences in shading should not be interpreted as indicating a significant difference in risk -- a subject discussed in section 4.1. Note that the numerical equivalence scale chosen for this programmatic chart (involving the larger values associated with the summation of risk at individual locations) is higher (by one order of magnitude or distance category) than the numerical equivalence scale for the location-specific 'pictograms' displayed in Section 3.3.

Discussion of comparative risks, as presented in this section, are based on reference to the actual data from the risk analysis; the quantitative comparisons can not be derived from the 'pictograms'. To support the programmatic (i.e., not location-specific) risk comparisons in this subsection, actual values for the risk measures for the five FPEIS alternatives are presented in Table 1; data are provided for the unmitigated case and for the two levels of mitigation.

Considering the case of unmitigated accident scenarios first, the continued storage alternative has the greatest probability of causing one or more fatalities of the five alternatives. The remaining four alternatives have approximately a factor of 10 lower probability of causing one or more fatalities.

The maximum number of fatalities of the five FPEIS alternatives ranges between approximately 5,000 and 90,000, with continued storage having the



Note Because this chart combines risk from all locations, the shading scale is a factor of 10 higher than the scale for all site-specific pictograms.

Numerical Equivalents

Legend

Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-2}$	>100,000	>0.1	$>10^{7}$	>0.1
		$10^{-3} - 10^{-2}$	10,000-100,000	$10^{-2} - 0.1$	$10^{6} - 10^{7}$	$10^{-2} - 0.1$
		$10^{-4} - 10^{-3}$	1000 - 10,000	$10^{-3} - 10^{-2}$	$10^{5} - 10^{6}$	$10^{-3} - 10^{-2}$
Lower		$<10^{-4}$	<1000	$<10^{-3}$	$<10^{5}$	$<10^{-3}$

FIGURE 8

RISK COMPARISON FOR PROGRAMMATIC ALTERNATIVES ALL LOCATIONS COMBINED

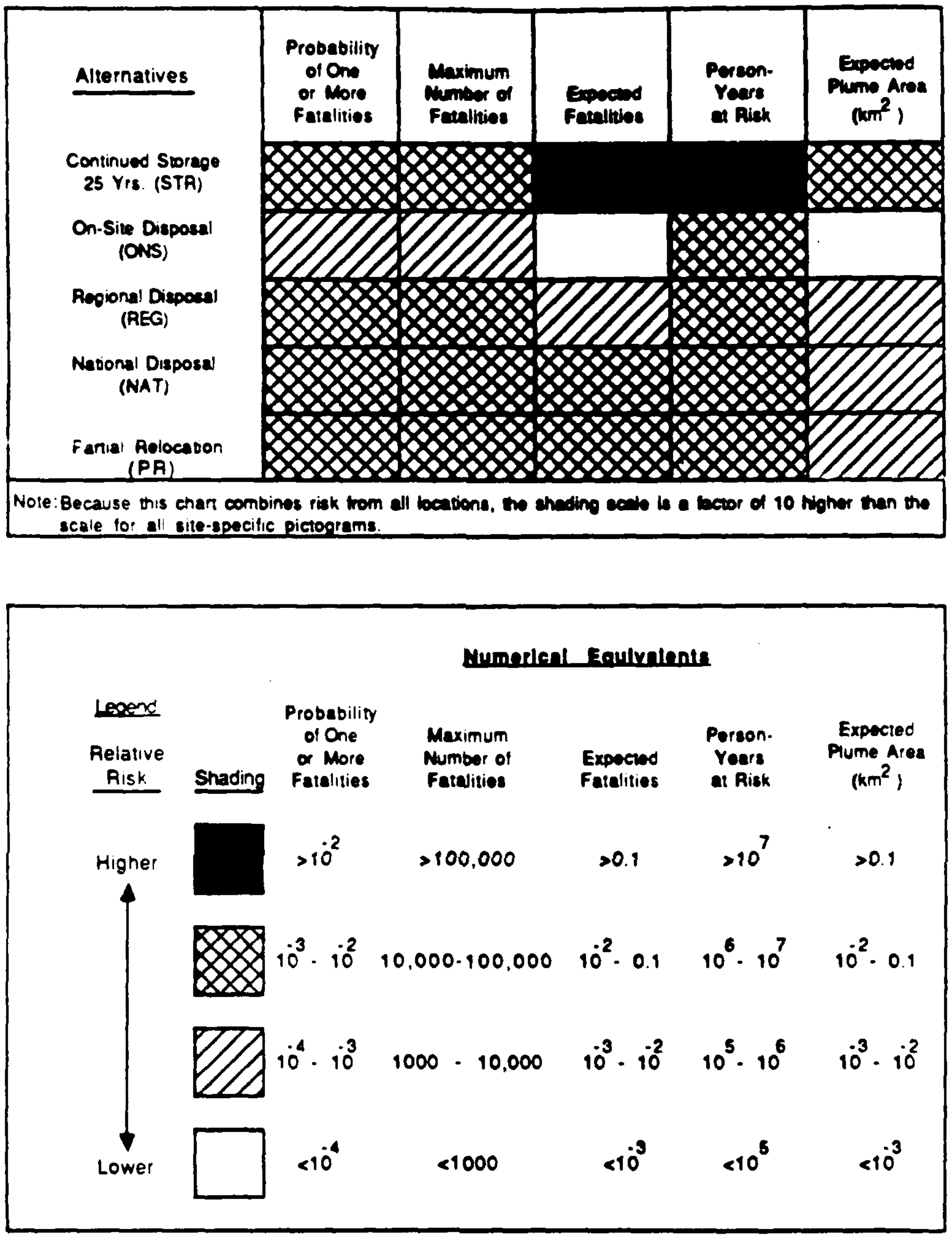
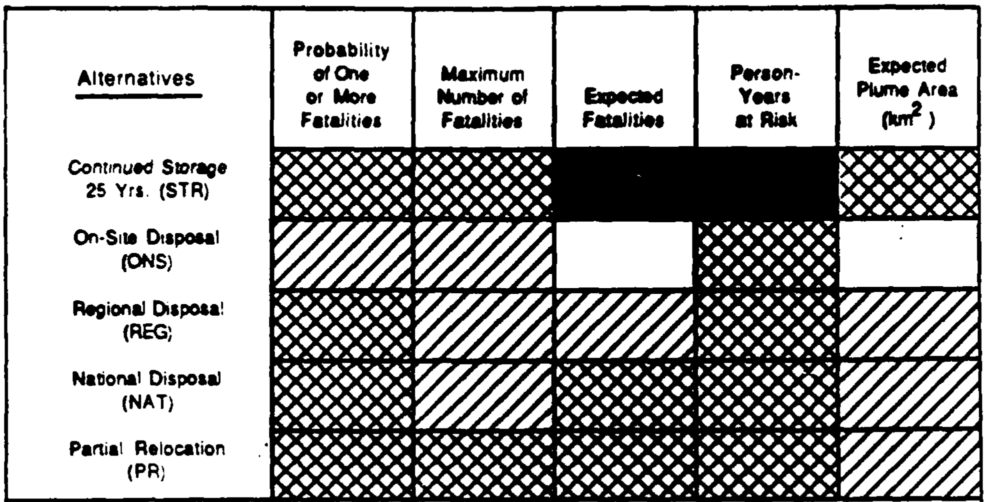


FIGURE 9

RISK WITH MITIGATION (REV. 1): COMPARISON FOR PROGRAMMATIC ALTERNATIVES ALL LOCATIONS COMBINED



Note: Because this chart combines risk from all locations, the shading scale is a factor of 10 higher than the scale for all site-specific pictograms.

Numerical Equivalents

Legend

Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-2}$	>100,000	>0.1	$>10^{7}$	>0.1
		$10^{-3} - 10^{-2}$	10,000-100,000	$10^{-2} - 0.1$	$10^{6} - 10^{7}$	$10^{-2} - 0.1$
		$10^{-4} - 10^{-3}$	1000 - 10,000	$10^{-3} - 10^{-2}$	$10^{5} - 10^{6}$	$10^{-3} - 10^{-2}$
Lower		$<10^{-4}$	<1000	$<10^{-3}$	$<10^{5}$	$<10^{-3}$

FIGURE 10

RISK WITH MITIGATION (REV. 2): COMPARISON FOR PROGRAMMATIC ALTERNATIVES ALL LOCATIONS COMBINED

TABLE 1
QUANTITATIVE COMPARISON OF RISK MEASURES FOR PROGRAMMATIC ALTERNATIVES -ALL LOCATIONS COMBINED-

A. Unmitigated Risk

Alternatives	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Continued Storage 25 Yrs. (STR)	6.4×10^{-2}	8.9×10^{4}	19.3	1.4×10^{8}	2.1
On-Site Disposal (ONS)	7.3×10^{-3}	5.4×10^{3}	1.0×10^{-2}	2.3×10^{6}	7.2×10^{-3}
Regional Disposal (REG)	4.8×10^{-3}	4.2×10^{4}	1.2×10^{-2}	5.5×10^{6}	9.3×10^{-3}
National Disposal (NAT)	5.1×10^{-3}	4.2×10^{4}	3.1×10^{-2}	5.4×10^{6}	1.2×10^{-2}
Partial Relocation (PR)	1.1×10^{-2}	2.3×10^{4}	3.4×10^{-2}	3.1×10^{6}	1.3×10^{-2}

B. Risk with Mitigation (Rev. 1)

Alternatives	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Continued Storage 25 Yrs (STR)	2.4×10^{-3}	8.9×10^{4}	4.5×10^{-1}	1.4×10^{8}	4.4×10^{-2}
On-Site Disposal (ONS)	3.2×10^{-4}	5.4×10^{3}	9.4×10^{-4}	2.3×10^{6}	4.6×10^{-4}
Regional Disposal (REG)	1.8×10^{-3}	4.2×10^{4}	9.5×10^{-3}	5.5×10^{6}	2.0×10^{-3}
National Disposal (NAT)	3.4×10^{-3}	4.2×10^{4}	3.0×10^{-2}	5.4×10^{6}	3.8×10^{-3}
Partial Relocation (PR)	3.7×10^{-3}	2.3×10^{4}	2.5×10^{-2}	3.1×10^{6}	6.6×10^{-3}

C. Risk with Mitigation (Rev. 2--with Air-Space Restrictions)

Alternatives	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Continued Storage 25 Yrs (STR)	1.3×10^{-3}	8.9×10^{4}	3.6×10^{-1}	8.9×10^{7}	3.7×10^{-1}
On-Site Disposal (ONS)	3.2×10^{-4}	5.4×10^{3}	9.4×10^{-4}	2.3×10^{6}	4.6×10^{-4}
Regional Disposal (REG)	1.8×10^{-3}	5.0×10^{3}	9.3×10^{-3}	1.9×10^{6}	2.0×10^{-3}
National Disposal (NAT)	3.4×10^{-3}	6.3×10^{3}	2.9×10^{-2}	1.8×10^{6}	3.8×10^{-3}
Partial Relocation (PR)	3.7×10^{-3}	2.3×10^{4}	2.5×10^{-2}	2.7×10^{6}	6.6×10^{-3}

greatest number and on-site disposal having the least. Continued storage has 16 times more maximum fatalities than on-site disposal; the national or regional alternatives have 7 times more than the on-site disposal alternative and the partial relocation alternative has 4 times more than the on-site disposal alternative.

The continued storage alternative has the greatest expected fatalities in the unmitigated case, while the on-site disposal and regional disposal alternatives have the least. The value of expected fatalities for the partial relocation and national disposal alternatives is approximately three times that for the on-site disposal alternative, while the value for the continued storage alternative (25 years) is approximately 1,900 times greater than for the on-site disposal alternative. This significant difference is not displayed on the pictogram, since the darkest shading category, in which continued storage falls, is unbounded on the higher end.

The difference between the expected fatalities for the continued storage alternative and the other four alternatives is more precisely shown in a plot of expected fatality estimates. Figure 11 portrays the expected fatality estimates, with upper and lower bounds, for each of the five unmitigated alternatives. The data show the dominance of expected fatalities associated with 25 years of continuing storage over expected fatalities associated with any of the seven disposal alternatives. Continued storage shows a mean expected fatality value of approximately 20, indicating that the analysis predicts a public fatality rate averaging roughly one per year. The fact that no deaths to the public have occurred after decades of storage does not mean the analysis is greatly in error or unduly conservative, rather, it is because the continued storage accidents are predicted to be infrequent (occurring far less frequently than 1 per year) but severe (multiple fatalities).

Person-years-at-risk are approximately equal for the on-site disposal and partial relocation alternatives. The national and regional disposal alternatives have approximately five times more person-years-at-risk than the on-site disposal alternative; and the continued storage alternative has approximately 60 times more person-years-at-risk than the on-site disposal alternative.

Expected plume area is greatest for the continued storage alternative, and least for the on-site disposal alternative.

For the mitigated accident scenarios, Figures 9 and 10 show that on-site disposal has the least probability of causing one or more fatalities. Compared to on-site disposal, the regional disposal alternative has approximately a 5 times greater probability of causing one or more fatalities, continued storage has approximately seven times greater probability of causing one or more fatalities, national disposal has approximately 10 times greater probability of causing one or more

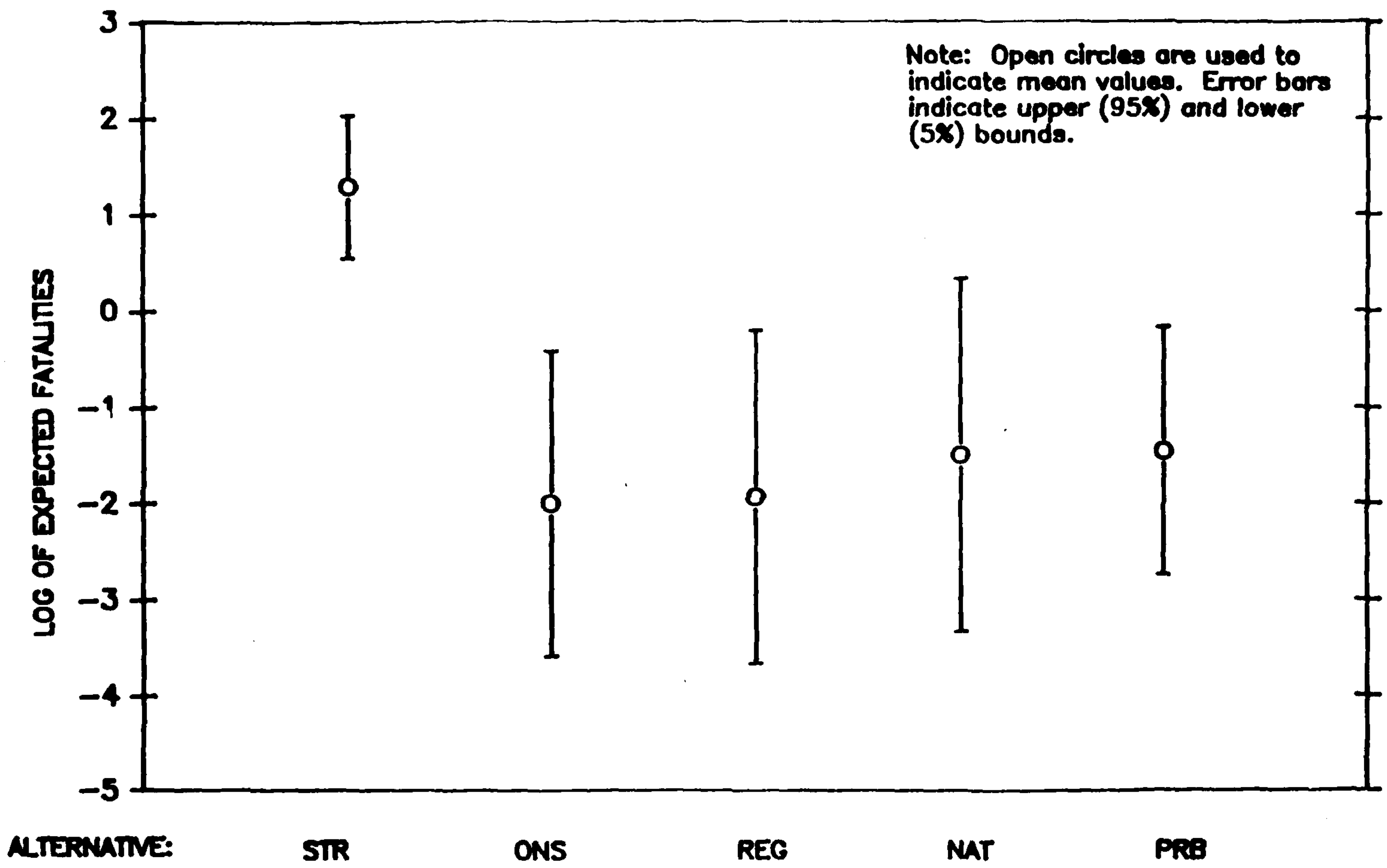


FIGURE 11

SOCIETAL RISK (EXPECTED FATALITIES) FOR PROGRAMMATIC ALTERNATIVES UNMITIGATED

fatalities, and the partial relocation alternative has approximately 11 times greater probability of causing one or more fatalities.

There was no change in the number of *maximum fatalities* possible or the person-years-at-risk for the mitigated accident scenarios. Also, addition of airspace restriction to the mitigation measures did not reduce risk to any significant degree from a programmatic standpoint.

For the mitigated (revision 1) accident scenarios, the continued storage alternative has the greatest expected fatalities, and on-site disposal has the least expected fatalities. Compared to on-site disposal, the value for expected fatalities is approximately 10 times greater for regional disposal, 26 times greater for partial relocation, 30 times greater for national disposal, and nearly 500 times greater for the continued storage alternative.

The greatest reduction in the probability of one or more fatalities for the mitigated accident scenarios, is in the on-site disposal and continued storage alternatives, which both showed greater than 90 percent reduction. The regional disposal and partial relocation alternatives showed approximately a 60 percent reduction in expected fatalities; and the national disposal alternative showed approximately a 40 percent reduction in the probability of one or more fatalities.

The greatest reductions in the value of expected fatalities for the mitigated accident scenarios also occurred in the continued storage and on-site disposal alternatives, which both show greater than 90 percent reduction from the unmitigated accident scenarios. The partial relocation alternative shows approximately a 25 percent reduction in the expected fatality value; the regional disposal alternative shows approximately 20 percent reduction in the expected fatality value; and the national disposal alternative shows approximately a 5 percent reduction in the expected fatality value.

As in the unmitigated case, the continued storage alternative has significantly more expected fatalities than all other alternatives. In addition, however, with addition of the accident mitigation measures, on-site disposal is rendered significantly less risky than the other disposal alternatives. (See Figures 12 and 13.)

3.2.2. Major Sources of Risk in Each Alternative

Figures 14 through 18 display the cumulative risk for the five FPEIS disposal alternatives, for the unmitigated accident scenarios (results for the other three disposal alternatives are presented and discussed in section 3.2.2.6.). Each curve shows the probability that the number of

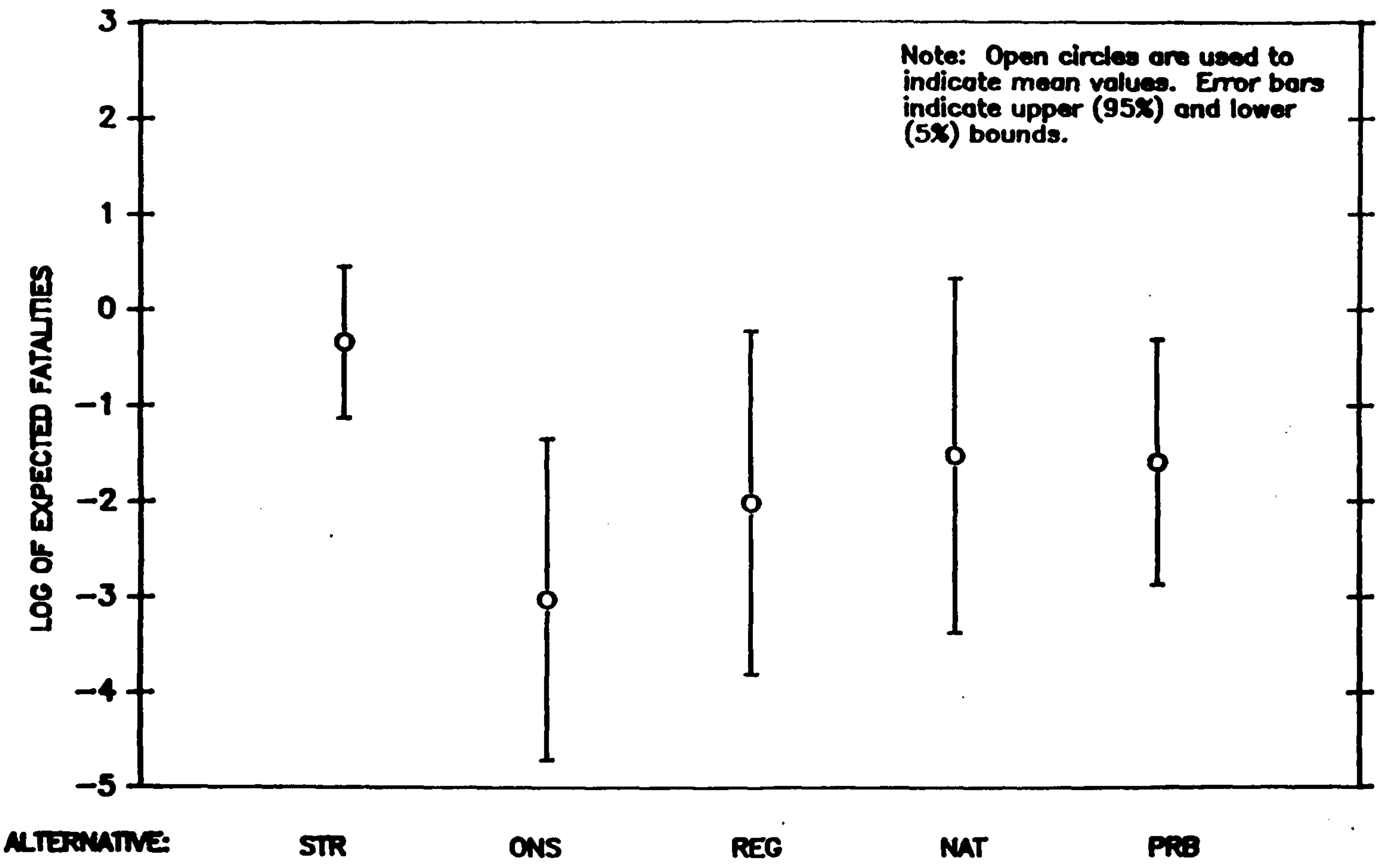


FIGURE 12

SOCIETAL RISK (EXPECTED FATALITIES)
FOR PROGRAMMATIC ALTERNATIVES
MITIGATED – NO AIR SPACE RESTRICTION

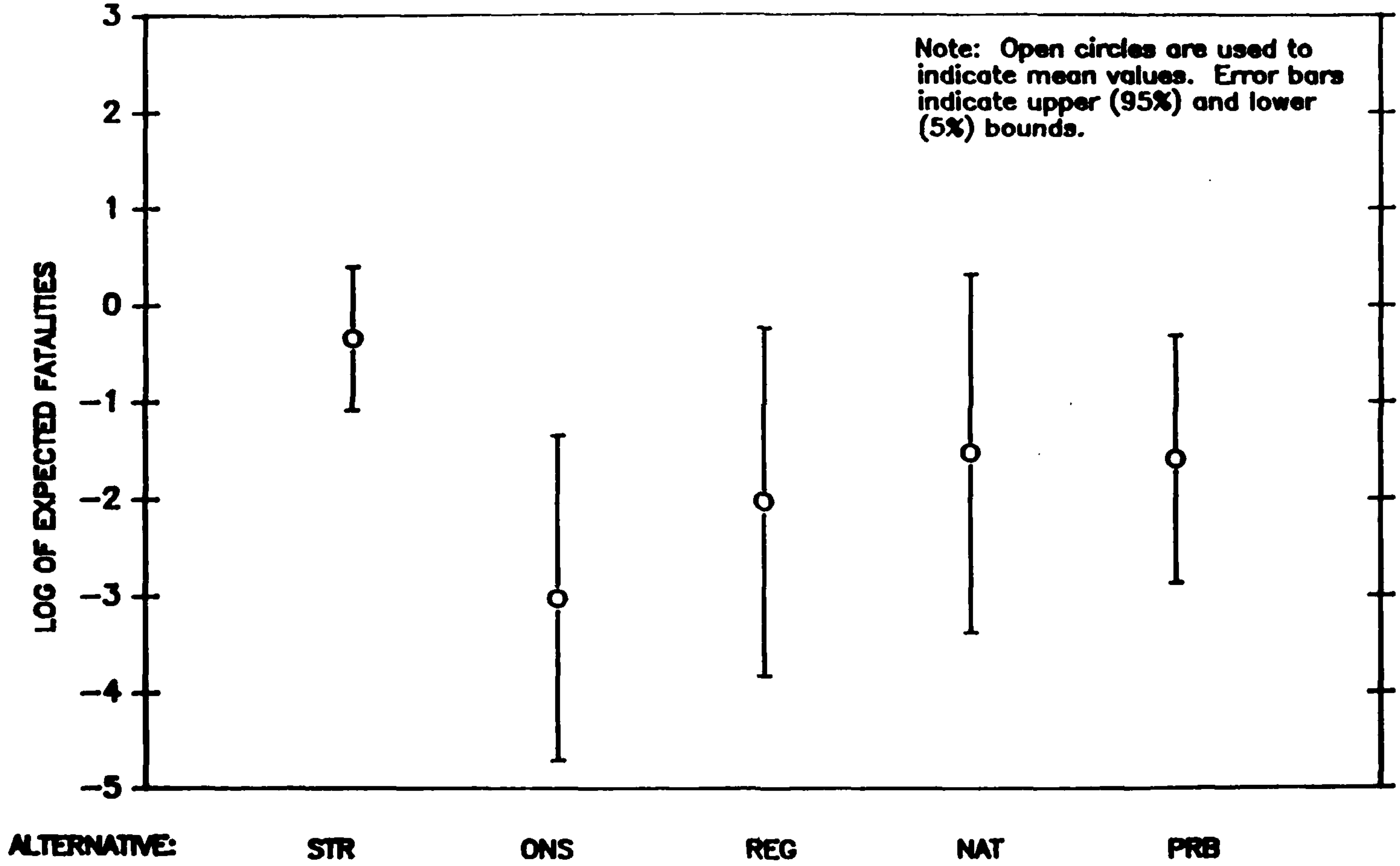


FIGURE 13

SOCIETAL RISK (EXPECTED FATALITIES)
FOR PROGRAMMATIC ALTERNATIVES
MITIGATED -- WITH AIR SPACE RESTRICTION

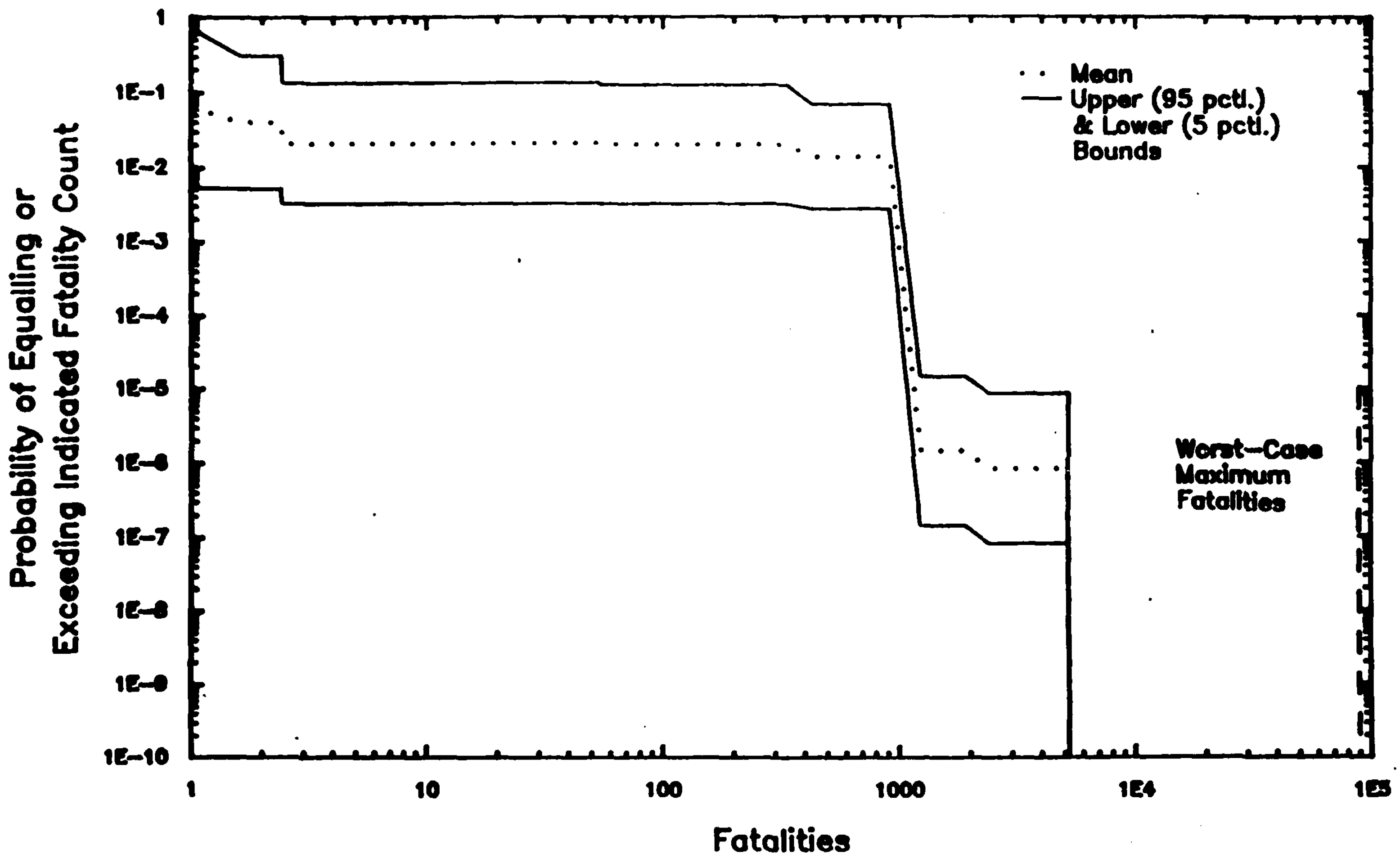


FIGURE 14

SOCIETAL RISK FOR PROGRAMMATIC ALTERNATIVE: STR
CONTINUED STORAGE – 25 YEARS

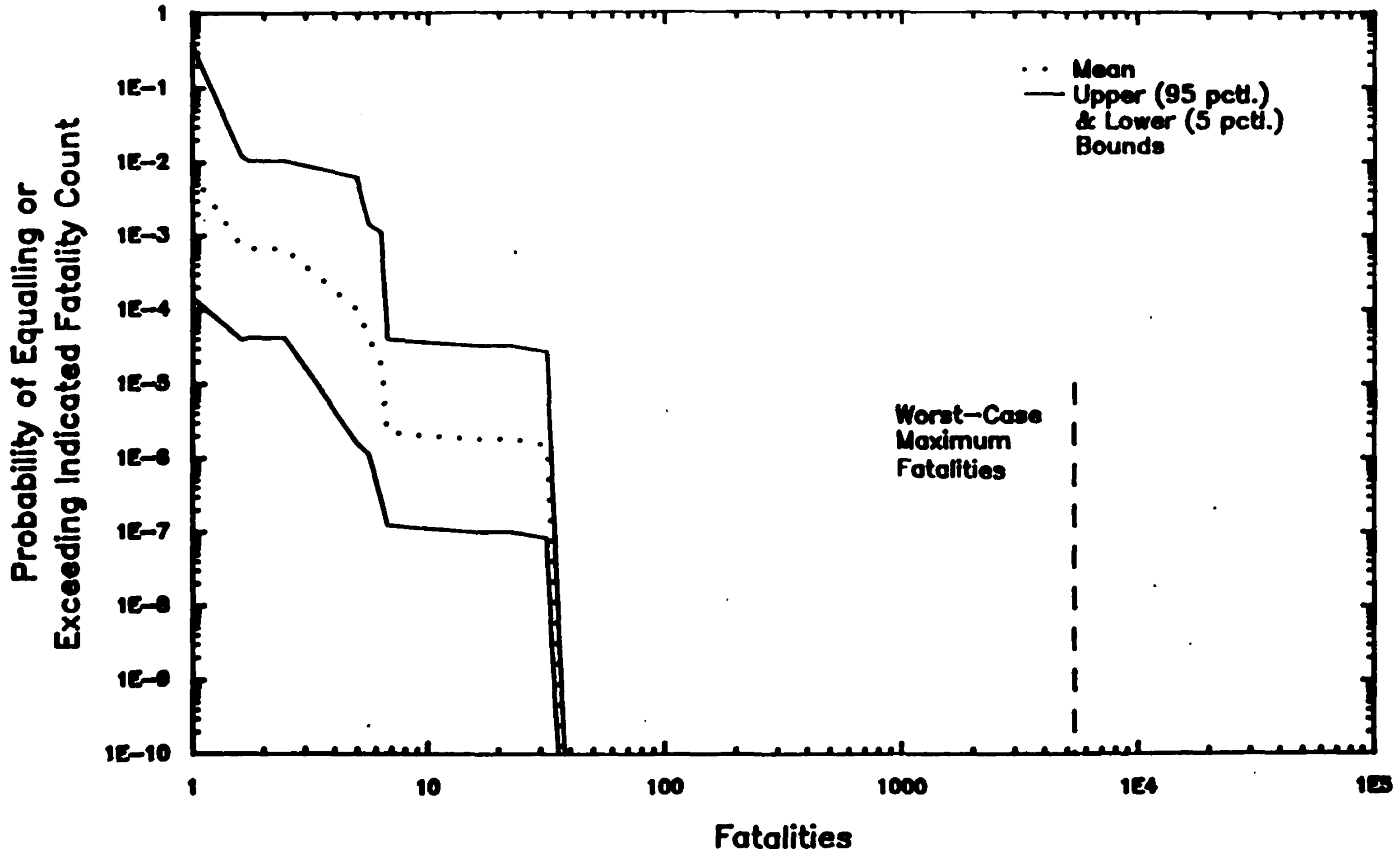


FIGURE 15

SOCIETAL RISK FOR PROGRAMMATIC ALTERNATIVE: ONS
ON-SITE DISPOSAL

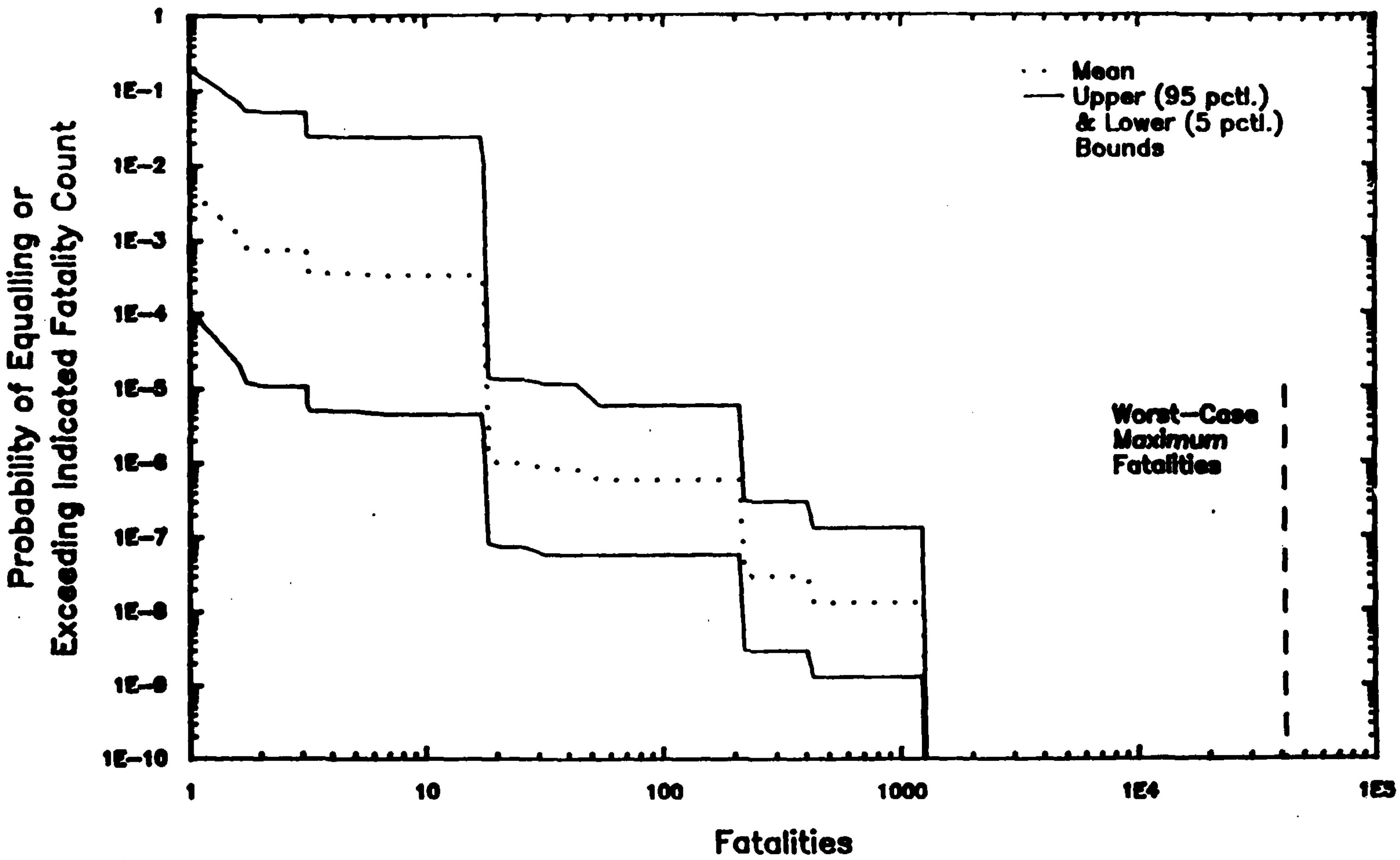


FIGURE 16

SOCIETAL RISK FOR PROGRAMMATIC ALTERNATIVE: REG REGIONAL DISPOSAL (RAIL)

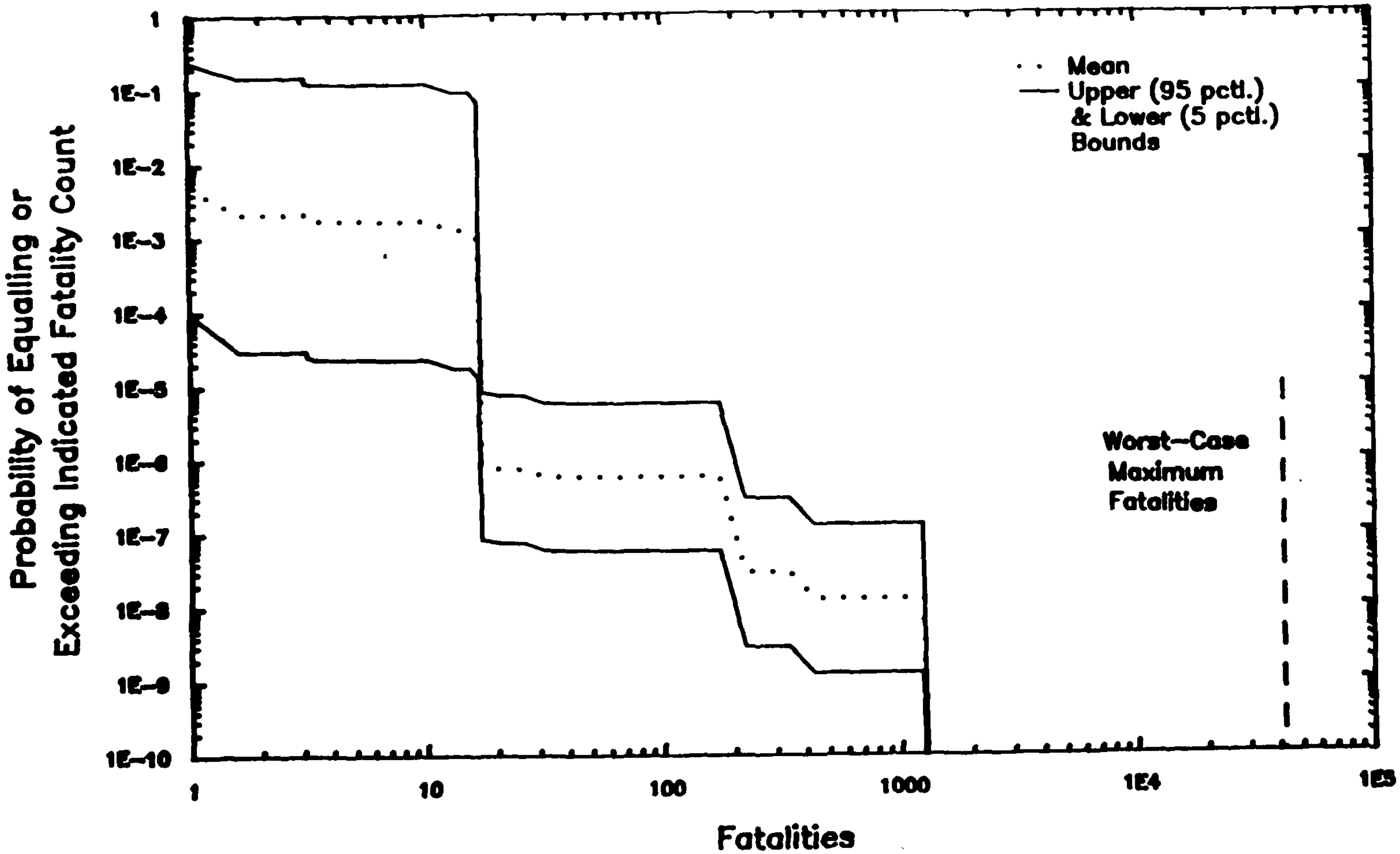


FIGURE 17

SOCIETAL RISK FOR PROGRAMMATIC ALTERNATIVE: NAT
NATIONAL DISPOSAL (RAIL)

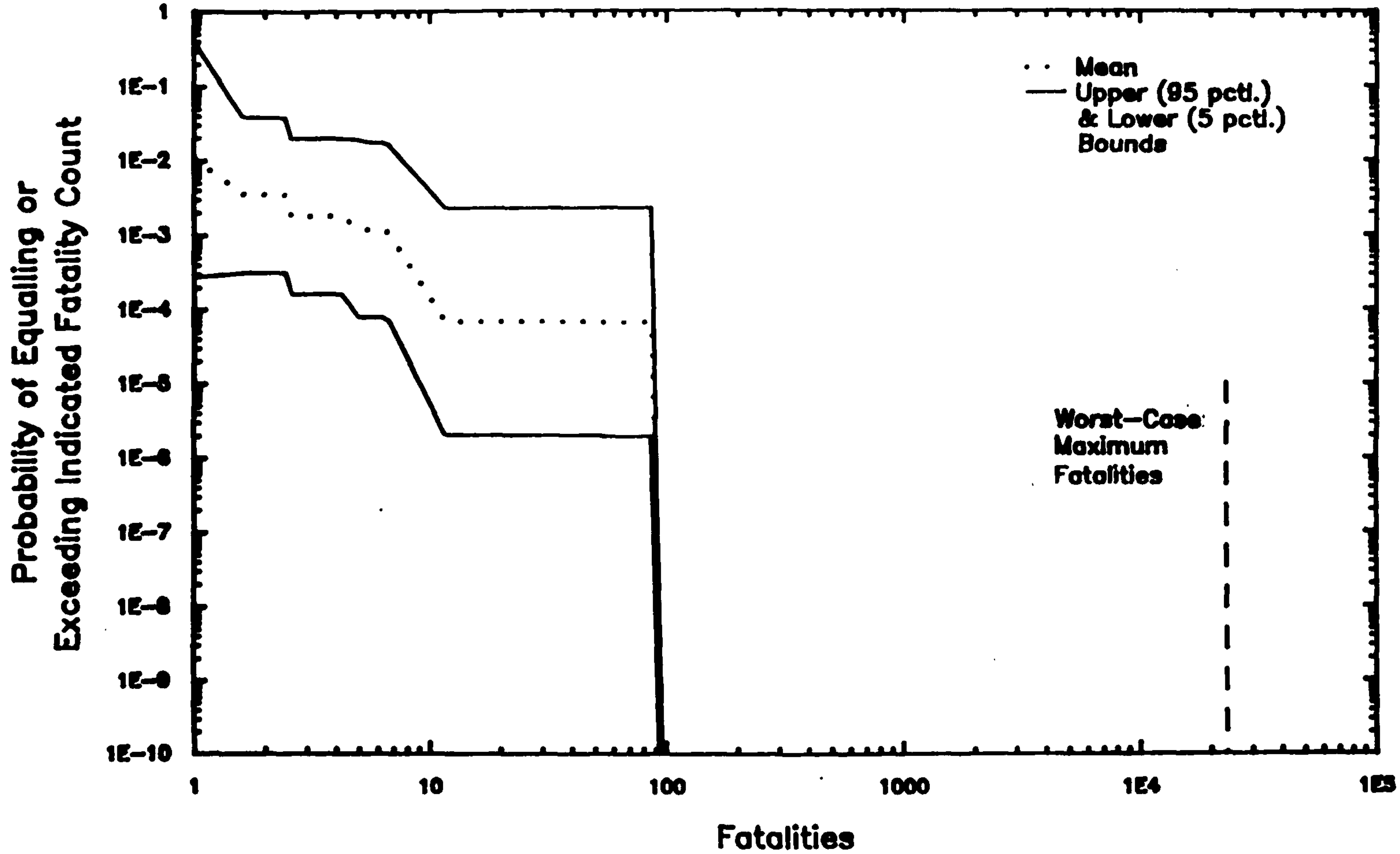


FIGURE 18

SOCIETAL RISK FOR PROGRAMMATIC ALTERNATIVE: PRB PARTIAL RELOCATION: APG & LBAD TO TEAD BY AIR (C141)

fatalities indicated by the horizontal scale is estimated to occur during the course of the entire disposal program. The intercept of the risk curve with the vertical axis, at a potential fatality of value of 1, is the probability of one or more fatalities -- one of the chosen major measures of programmatic risk. The area under each risk curve is numerically equal the course of the entire disposal program. The intercept of the risk curve with the vertical axis, at a potential fatality of value of 1, is the probability of one or more fatalities -- one of the chosen major measures of programmatic risk. The area under each risk curve is numerically equal to another of the principal risk measures -- the **expected fatalities** of the alternative (see note in section 2.3). Finally, the horizontal intercepts (at probability = 10^{-10}) indicate the **maximum fatalities** that potentially could occur, although at very low probability, during the execution of the disposal alternative. The intercept for the lower bound curve indicates **maximum fatalities** for *most-likely* meteorology with wind directed at the average population density; the dashed vertical line at the right of each curve indicates the **maximum fatalities** for *worst-case* meteorology with wind directed toward the maximum potentially affected population. The latter value for **maximum fatalities** (i.e., worst-case conditions) is the measure represented in the 'pictograms'.

The risk curves show mean values as the dotted curve, as well as upper and lower uncertainty bounds (95 percent and 5 percent levels). The uncertainty bounds have been estimated through the use of the range factor data supplied by GA Technologies as a part of the accident scenario data base (GA Technologies, 1987[a], 1987[b], 1987[c]). The method for estimating uncertainty for a programmatic alternative is presented in Appendix B of this report. Note that the uncertainty estimates are based on uncertainty in the estimated probability that an accident will take place, not on uncertainty in the consequence of an accident; nor do the uncertainty estimates include the uncertainty in population density, atmospheric conditions, and dose response. Uncertainty in wind direction is implied by assuming a uniform wind rose (equal probability for any direction) in conjunction with the assumptions of most-likely meteorological conditions and average population densities used for all probabilistic risk computations.

The effects of mitigation for each of the five FPEIS disposal alternatives are displayed by the cumulative risk curves in Figures 19 through 23. These risk curves do not show the uncertainty bands, which are well represented by Figures 14 through 18 but, instead, show three mean value curves -- one for each level of mitigation.

3.2.2.1 *Continued Storage*. The programmatic risk due to the continued storage alternative for the *unmitigated* case is portrayed in Figure 14. The risk is made up of both internally- and externally-initiated potential accidents. Storage of bulk containers accounts for 99

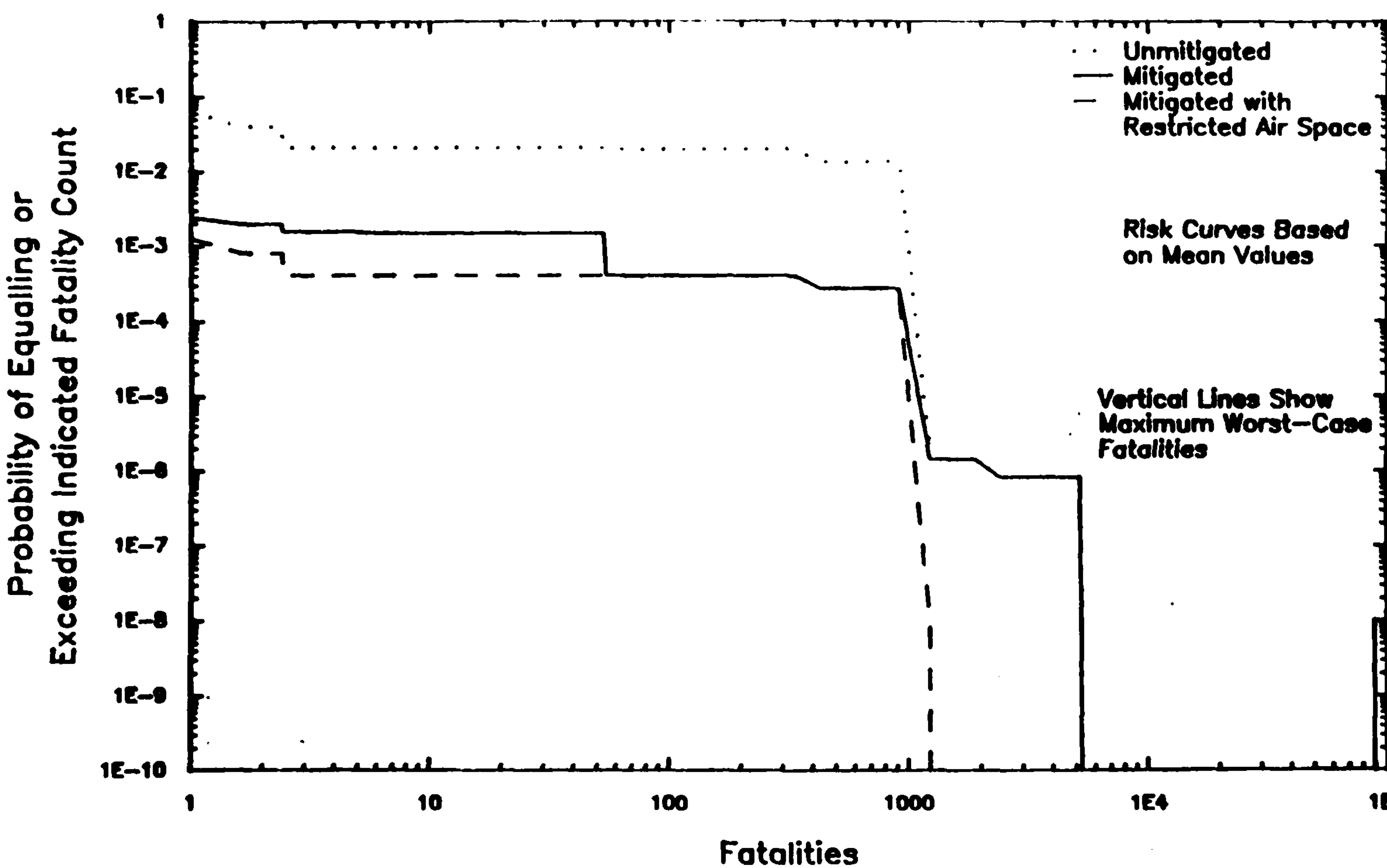


FIGURE 19

SOCIETAL RISK FOR PROGRAMMATIC ALTERNATIVE: STR
CONTINUED STORAGE – 25 YEARS – SHOWING EFFECTS OF MITIGATION

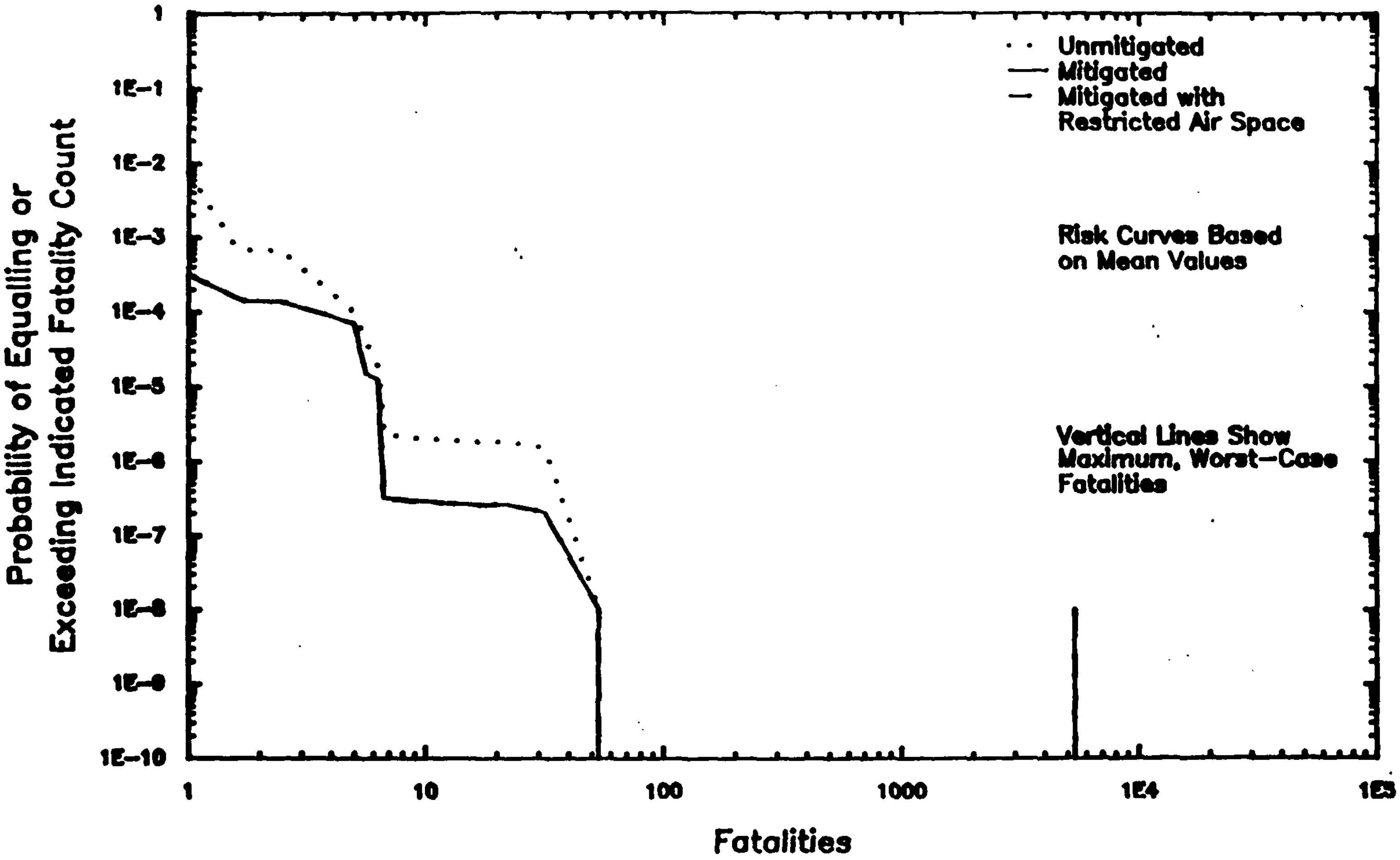


FIGURE 20

SOCIETAL RISK FOR PROGRAMMATIC ALTERNATIVE: ONS ON-SITE DISPOSAL – SHOWING EFFECTS OF MITIGATION

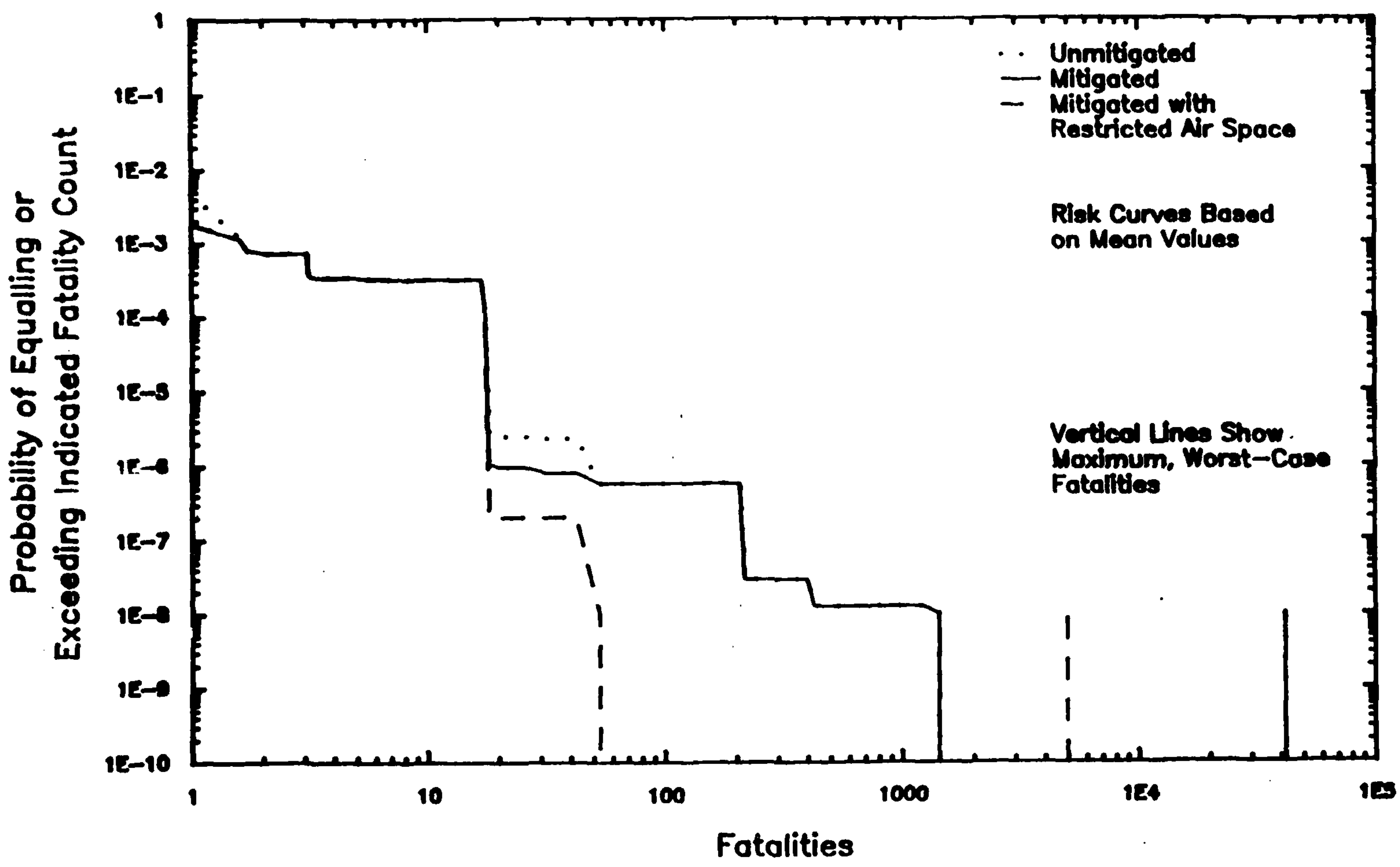


FIGURE 21

SOCIETAL RISK FOR PROGRAMMATIC ALTERNATIVE: REG
REGIONAL DISPOSAL (RAIL) -- SHOWING EFFECTS OF MITIGATION

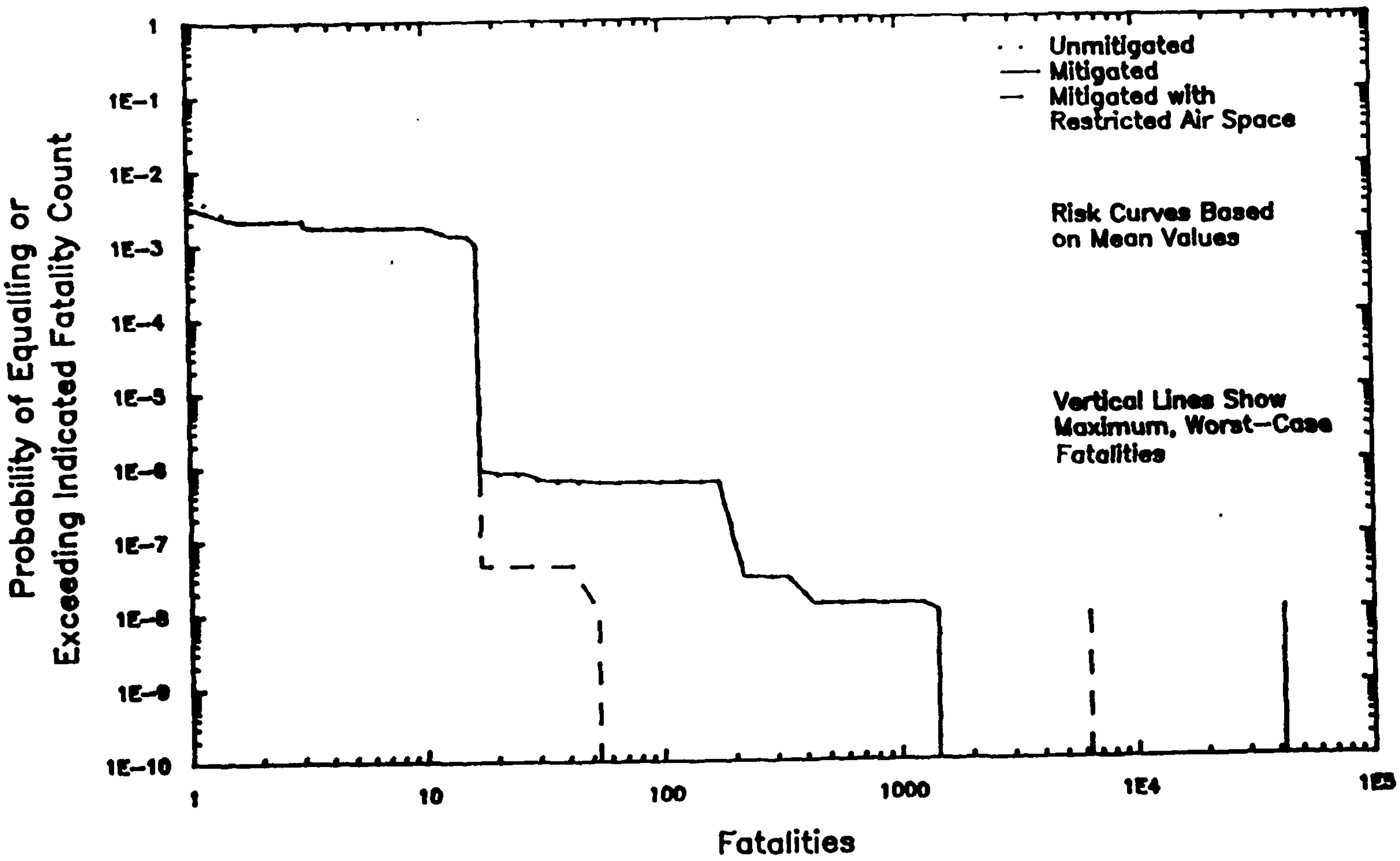


FIGURE 22

SOCIETAL RISK FOR PROGRAMMATIC ALTERNATIVE: NAT NATIONAL DISPOSAL (RAIL) -- SHOWING EFFECTS OF MITIGATION

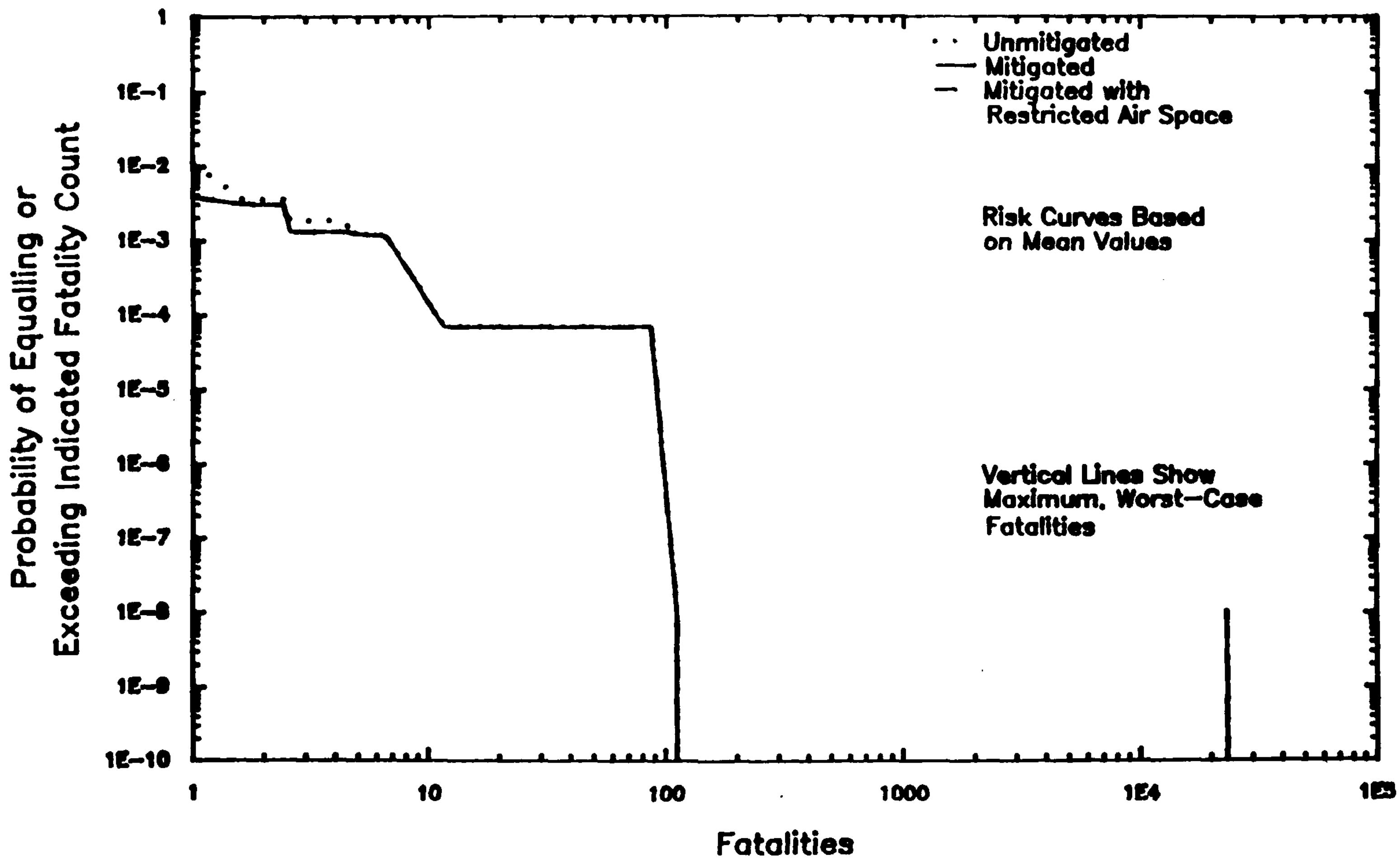


FIGURE 23

SOCIETAL RISK FOR PROGRAMMATIC ALTERNATIVE: PRB PARTIAL RELOCATION: APG & LBAD TO TEAD BY AIR (C141) SHOWING EFFECTS OF MITIGATION

percent of the risk. Externally-initiated events, and, in particular, relatively mild earthquakes that result in fires affecting warehouse storage of bulk containers of mustard or VX at three sites (NAAP, UMDA, and TEAD), account for nearly all of the risk as measured by expected fatalities (the area under the cumulative risk curve), with earthquakes at the NAAP warehouse dominating. The probability of these earthquake events occurring in any given year is in the range of 10^{-4} to 10^{-5}, and the amount of agent potentially released is in the range of 10,000 to 100,000 pounds the NAAP warehouse dominating. The probability of these earthquake events occurring in any given year is in the range of 10^{-4} to 10^{-5}, and the amount of agent potentially released is in the range of 10,000 to 100,000 pounds or more -- an amount which, because it can released as a vapor cloud fed by burning agent, can cause downwind plume lengths ('no-deaths' hazard distances, most-likely weather) of 20 to 50 km. Such large plumes could result in large numbers of fatalities, even in remote areas.

The next most significant contributor to risk of continued storage is the result of another external event -- a small aircraft crash into the open storage yard, containing ton containers of mustard, at APG. Like the warehouse accidents, this scenario involves the fire-induced release of mustard agent. The frequency expected for this accident is 10^{-5} per year and the quantity of agent released is in the range of 5000 lbs, which can result in a plume length of approximately 3 km.

The analysis has identified a number of highly probable agent-releasing handling accidents associated with movement of the stockpile for maintenance and surveillance. These accidents, although estimated to occur more frequently than earthquakes or aircraft accidents (frequency of 10^{-2} per year) release small quantities of agent since the contents of only one munition or pallet is involved, and the accident can be cleaned up more quickly. Because the release quantities are smaller, the downwind hazard distances are less. Therefore, handling accidents during storage do not contribute significantly to the population risks associated with the continued storage alternative.

The risk curve shows that accidents with consequences greater than 5000 fatalities could occur. These accidents involve aircraft crashing into the warehouse at NAAP resulting in fire-induced release of agent VX. However, the probability of these potential accidents is less than 10^{-7}, and the resulting contribution to expected fatalities is relatively low. The risk curve also shows a probability of one or more fatalities (the Y-axis intercept) to be 0.05 with a range factor of approximately 10. This means that the chance of a fatal accident (one or more deaths) <u>per year</u> is 0.05/25 = 0.002, with the same range factor. Thus, the risk analysis predicts a fatal event every 500 years (500 = 1/0.002), give or take a factor of 10.

The effects of mitigation are portrayed in Figure 19. For the case of Mitigation, Revision 1, the risk analysis shows that the probability of one or more fatalities is reduced by a factor of approximately 26, while expected fatalities decreases by a factor of approximately 42. There is no change to the maximum number of fatalities or the person-years-at-risk for this alternative. Storage activities account for approximately 99 percent of the expected fatalities, while handling associated with movement of the stockpile for maintenance and surveillance during continued storage accounts for the remainder. Bulk containers account for approximately 99 percent of the expected fatalities. With the introduction of Mitigation, Revision 2, the probability of one or more fatalities is reduced by approximately a factor of 2, and the expected fatalities are approximately equal.

3.2.2.2 On-Site Disposal. The programmatic risk of on-site disposal for the unmitigated case is displayed in Figure 15. Several activity categories contribute to on-site disposal risk; 93 percent being caused by chemical disposal plant operations; 2 percent caused by handling in the storage area and at the disposal facility; and, 4 percent being caused by on-site transportation. The major contributors to on-site disposal risk are earthquakes damaging the disposal plant and human-error-induced accidents involving inadvertent feed of a burstered munition to the dunnage incinerator. These accidents are among the most frequent of all those identified for this alternative; they have a probability of occurring during the stockpile program of approximately 10^{-3}. The agent release for the earthquake scenario is large because the munition demilitarization building (MDB) is assumed to be severely damaged and bulk agent quantities and/or multiple munitions are involved; the estimated potential release, via fire, is sufficient to generate a lethal plume approximately 3 km long. The dunnage furnace scenarios involve lesser release quantities, since only single munitions are involved. Aircraft crashes into the disposal plant do not contribute significantly to risk because of the relatively small size of the target and of the local inventory available for release, and because of the relatively short time the plant is in operation (<3 years at most sites).

On-site transport of munitions also contributes significantly to on-site risk because large quantities of agent can be involved in vehicle accidents, and because the probability of occurrence, although only 10^{-10} accidents per vehicle-mile, is relatively high because there are many vehicle-miles involved in the CSDP.

Handling accidents which contribute most significantly to on-site risk are the dropping of an on-site container or a pallet of munitions.

The on-site disposal alternative has the lowest maximum consequence accident (most-likely meteorological conditions) of any alternative. The

maximum potential fatality event could cause an estimated 54 deaths (under these most-likely conditions) as a result of either an earthquake, leading to a fire in the disposal plant, or a serious on-site transport vehicle accident; all these maximum consequence accidents involve the fire-borne or detonation-caused release of agent VX.

In addition to the dunnage incinerator accidents discussed above, other accidents having probabilities in the range of 10^{-4} to 10^{-3} per stockpile also include handling operations both at the storage yard and at the plant; these handling accidents, with the exception of accidents during handling of ton-containers containing GB, do not result in consequences beyond the boundaries of the military reservation.

The effects of mitigation are portrayed in Figure 20. For the case of Mitigation, Revision 1, the probability of one or more fatalities is reduced by a factor of approximately 22, while expected fatalities decreases by a factor of approximately 10. On-site transportation activities account for approximately 44 percent of the expected fatalities, while plant operations account for approximately 48 percent. Fifty percent of the expected fatalities can be attributed to rockets, and approximately 42 percent to bulk containers. Expected fatalities caused by plant operations activities were reduced by a factor of approximately 20 while expected fatalities caused by handling activities were reduced by approximately a factor of 4. There is no additional reduction in risk with the introduction of Mitigation, Revision 2.

3.2.2.3 Regional Disposal (Rail). Figure 16 illustrates the programmatic risk for the unmitigated regional disposal alternative. Over 60 percent of the total risk (expected fatalities) is due to potential off-site transport accidents; 25 percent of the risk is due to plant operations and less than 10 percent results from on-site transport; short-term storage and handling together contribute less than 5 percent to total risk. Of the risk contributed by off-site transportation, 80 percent is due to the transport of rockets, followed in significance by an 11 percent contribution due to transport of mines. Of total regional disposal risk, over 60 percent is due to rockets.

Among individual accident scenarios, those contributing most to risk are due to off-site rail transport of rockets. Of nearly equal risk are dunnage incinerator accidents involving rockets and mines.

In contrast to the on-site disposal risk curve (Figure 15), the regional alternative includes potential accidents with much higher consequences (most likely conditions): greater than 1400 maximum fatalities vs. 54 for on-site. The highest consequence event involves short-term storage of the transportation containers of rockets in the holding area.

However, the probability of this high consequence accident is low: less than 10^{-7}.

The highest probability accidents for this alternative are those due to inadvertent feeding of burstered munitions into the dunnage incinerator and handling accidents involving single munitions or a pallet of munitions. These high probability accidents are not of sufficient consequence, under most-likely conditions, to cause fatalities beyond the boundaries of the military reservation with the exception of dunnage furnace accidents involving mines and rockets.

The effects of mitigation are portrayed in Figure 21. For the case of Mitigation, Revision 1, the probability of one or more fatalities is reduced by a factor of 2, while the expected fatalities does not significantly decrease. Plant operations expected fatalities were decreased by a factor of 47. Off-site transportation activities account for approximately 77 percent of the expected fatalities, on-site transportation accounts for approximately 18 percent of the expected fatalities, and the remainder is distributed among the handling, storage, and plant operations activities. Rockets account for approximately 66 percent of the expected fatalities, while projectiles and mines account for approximately 14 and 11 percent of the expected fatalities respectively. With the introduction of Mitigation, Revision 2, the maximum fatalities are reduced by a factor of approximately 7. There is no reduction in the probability of one or more fatalities or in the expected fatalities.

3.2.2.4 National Disposal (Rail). The programmatic risk due to the national disposal alternative without mitigation is portrayed by Figure 17. The risk curve appears to be very similar to that for regional disposal, as one might expect since the mix of activities is the same, with the major differences due to where the accidents might take place. Relative to regional disposal, the national alternative involves the transportation of the ANAD stockpile to TEAD and the shift of all plant operations to TEAD.

Of the total risk, approximately 90 percent is caused by off-site transportation and less than 5 percent is caused by chemical disposal plant operations. Of the off-site transportation risk, over 95 percent is caused by transportation of energetic munitions, approximately 55 percent of that being caused by transportation of rockets, and 25 percent by transportation of projectiles.

As with regional disposal, the major contributors to risk among individual accident scenarios are the off-site rail transportation accidents. However, for this alternative, the highest risk accidents include those due to projectiles and mines, representing the risk due to transport of the ANAD stockpile to TEAD.

The highest consequence scenario, involving potential fatalities of over 1400, is the same as for the regional alternative: short-term storage of rockets in the holding area.

Highest probability accidents (probability greater than 10^{-4}) for national disposal are due to plant operations (inadvertent feed of burstered munitions to dunnage incinerator), handling, and off-site rail transportation. Of these, the handling accidents do not lead to plume lengths which exceed the boundary of the military reservation with the exception of those involving ton containers of GB, and therefore do not contribute significantly to risk.

The effects of mitigation are portrayed in Figure 22. For the case of Mitigation, Revision 1, there is no significant reduction in the probability of one or more fatalities or the expected fatalities. Approximately 97 percent of the expected fatalities are caused by off-site transportation activities. Rockets account for approximately 56 percent of the expected fatalities, while projectiles and mines account for approximately 28 and 7 percent respectively. With the introduction of Mitigation, Revision 2, maximum fatalities are reduced by a factor of approximately 7. There is no significant reduction in the probability of one or more fatalities or in expected fatalities.

3.2.2.5 Partial Relocation: APG & LBAD to TEAD by Air(C141). Programmatic risk for the unmitigated partial relocation alternative, on-site disposal at all sites except for transport of the APG and LBAD stockpiles to TEAD via C141 aircraft, is shown in Figure 18. Of total risk, 71 percent is due to off-site transportation and 27 percent results from plant operations. Accidents involving rockets contribute 77 percent of total risk. In-flight air accidents (along the transportation corridor) account for 46 percent of total risk for this alternative.

The highest consequence accidents, under most-likely conditions, for this alternative (112 potential fatalities) are due to aircraft take-off accidents involving rockets and projectiles containing GB.

The probability of one or more fatalities for this alternative is approximately 10^{-2}.

The effects of mitigation are portrayed in Figure 23. For the case of Mitigation, Revision 1, the probability of one or more fatalities is reduced by approximately a factor of 3, while expected fatalities, the area under the curve (on rectilinear scales), does not significantly decrease. Plant operations activities show the greatest expected fatalities reductions, reduced by approximately a factor of 21. Expected fatalities caused by mines were reduced approximately a factor of 21, while expected fatalities caused by bulk containers were reduced by approximately

a factor of 4. There is no additional reduction in risk with the introduction of Mitigation, Revision 2.

3.2.2.6 Other Partial-Relocation Alternatives. As noted above (section 3.1.1), three partial relocation disposal alternatives (those involving use of the C5 aircraft or water-mode transport of the APG stockpile to Johnston Island) were initially treated in the risk analysis but were subsequently screened from further consideration in the mitigation analysis and in the FPEIS. Risk analysis results for those three alternatives will be summarized in this section.

Expanded 'pictograms' comparing the programmatic risk for all eight disposal alternatives in the vicinity of the disposal/storage sites and along the air and water mode transportation corridors are shown in Figures 24a and 24b, respectively. Thess 'pictograms' display seven measures of risk, including the two individual risk measures which are not a part of the 'pictograms' prepared subsequent to the selection of the five FPEIS disposal alternatives. Figure 25 is the expected fatalities chart for all eight alternatives. The risk curves for the eliminated alternatives are presented as Figures 26 through 28. The major features of programmatic risk for these three partial relocation alternatives are summarized below.

An examination of Figures 24 and 25 shows that, among the disposal alternatives (not including continued storage), alternative PRA -- partial relocation of the APG and LBAD stockpiles by air (C5) to TEAD with all other stockpiles disposed of on-site -- appears to be significantly more risky (on the basis of expected fatalities), by approximately a factor of 10. Whether or not the difference between PRA and the other disposal alternatives, all of which appear to pose approximately the same risk in terms of expected fatalities, is statistically significant will be discussed in section 4.1.

Partial Relocation: APG & LBAD to TEAD by Air (C5). In Figure 26, programmatic risk for the partial relocation alternative, PRA, consisting of on-site disposal at all sites except for movement of the APG and LBAD stockpiles to TEAD via C5 aircraft is portrayed. Of the total risk, measured as expected fatalities, 95 percent is due to off-site transportation (all by air mode), and most of the remaining 5 percent results from plant operations. Of the off-site transportation risk, two-thirds takes place along the transportation corridors and the remaining third takes place at the originating site in the form of take-off accidents; less than 2 percent of the transportation risk is experienced at the destination site (TEAD), and that risk is in the form of accidents during landing. Among munition types, rockets account for nearly 90 percent of the total risk for this alternative.

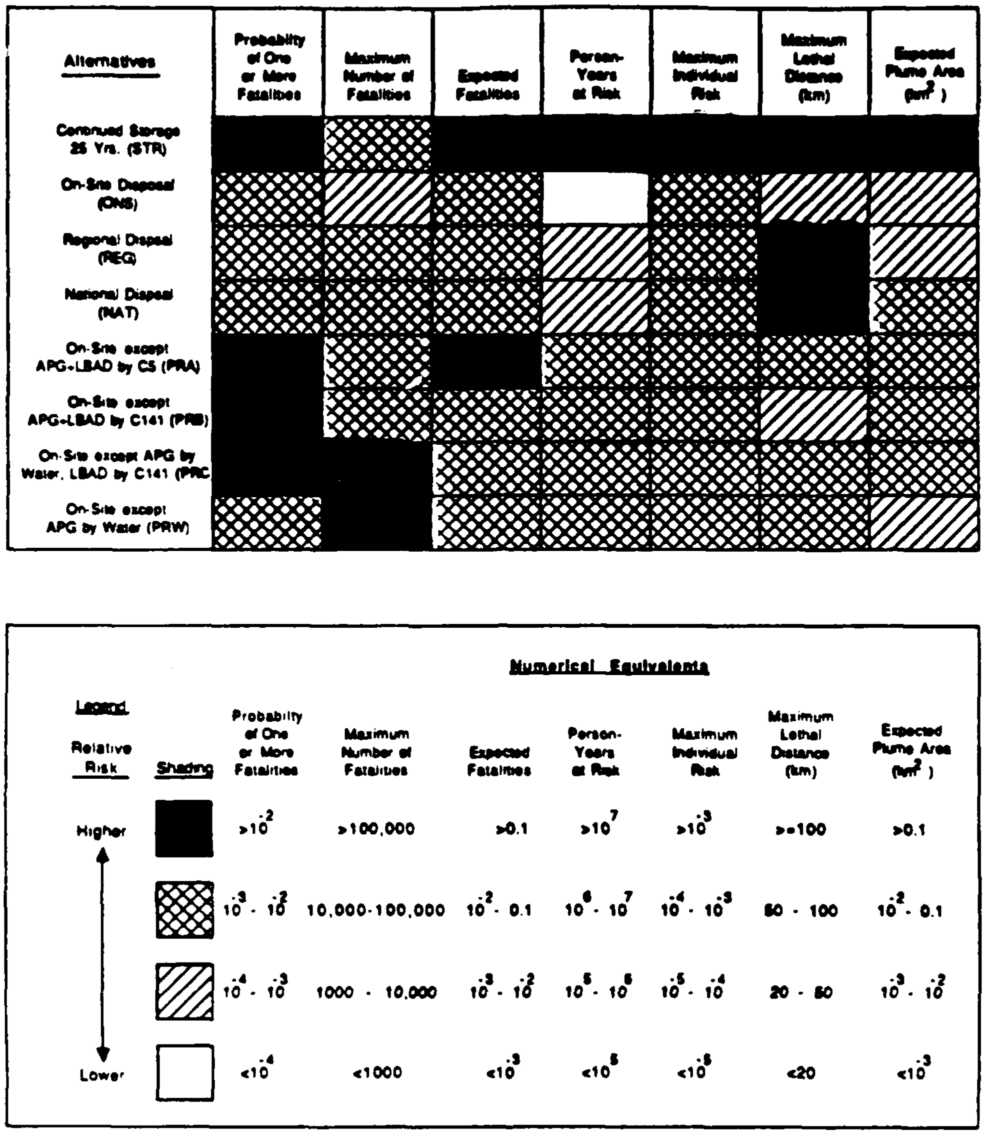


FIGURE 24A

**RISK COMPARISON FOR EIGHT PROGRAMMATIC ALTERNATIVES
ALL LOCATIONS COMBINED
- UNMITIGATED -**

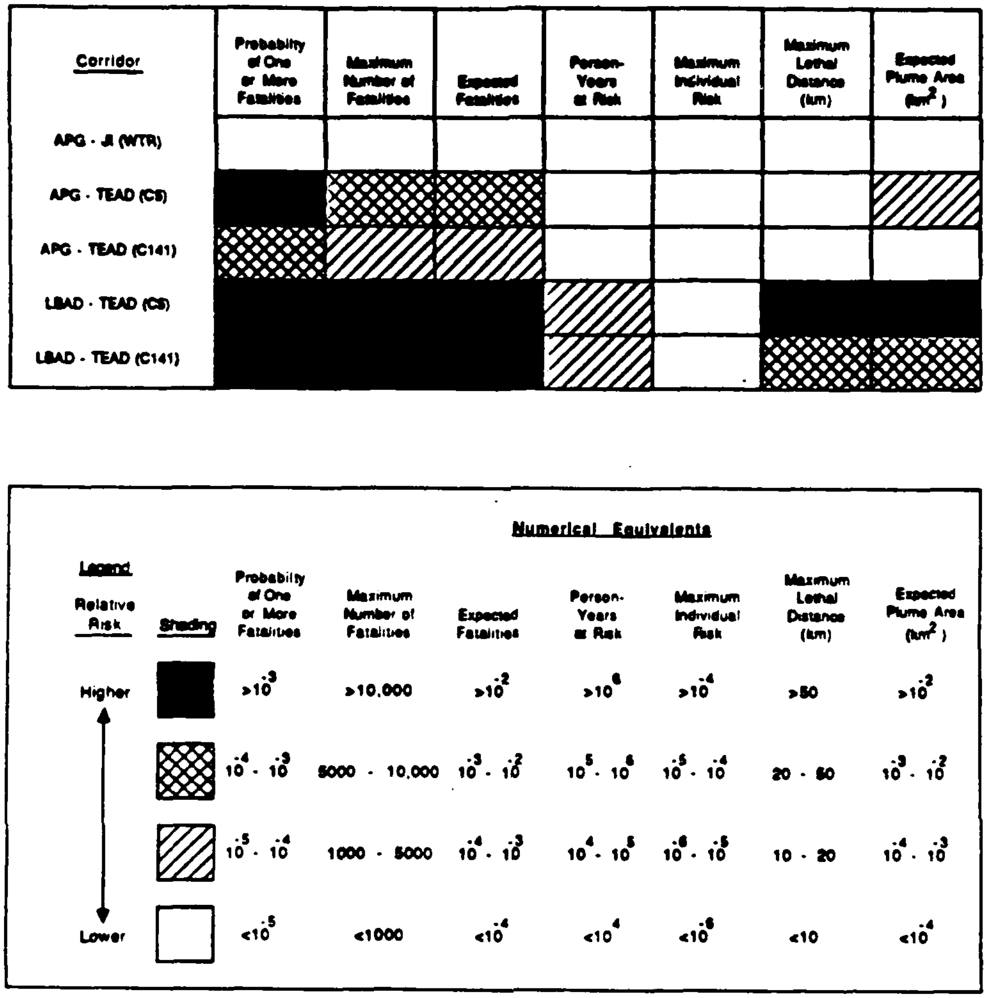


FIGURE 24B

RISK ALONG AIR AND WATER TRANSPORTATION CORRIDORS FOR PARTIAL RELOCATION DISPOSAL
- UNMITIGATED -

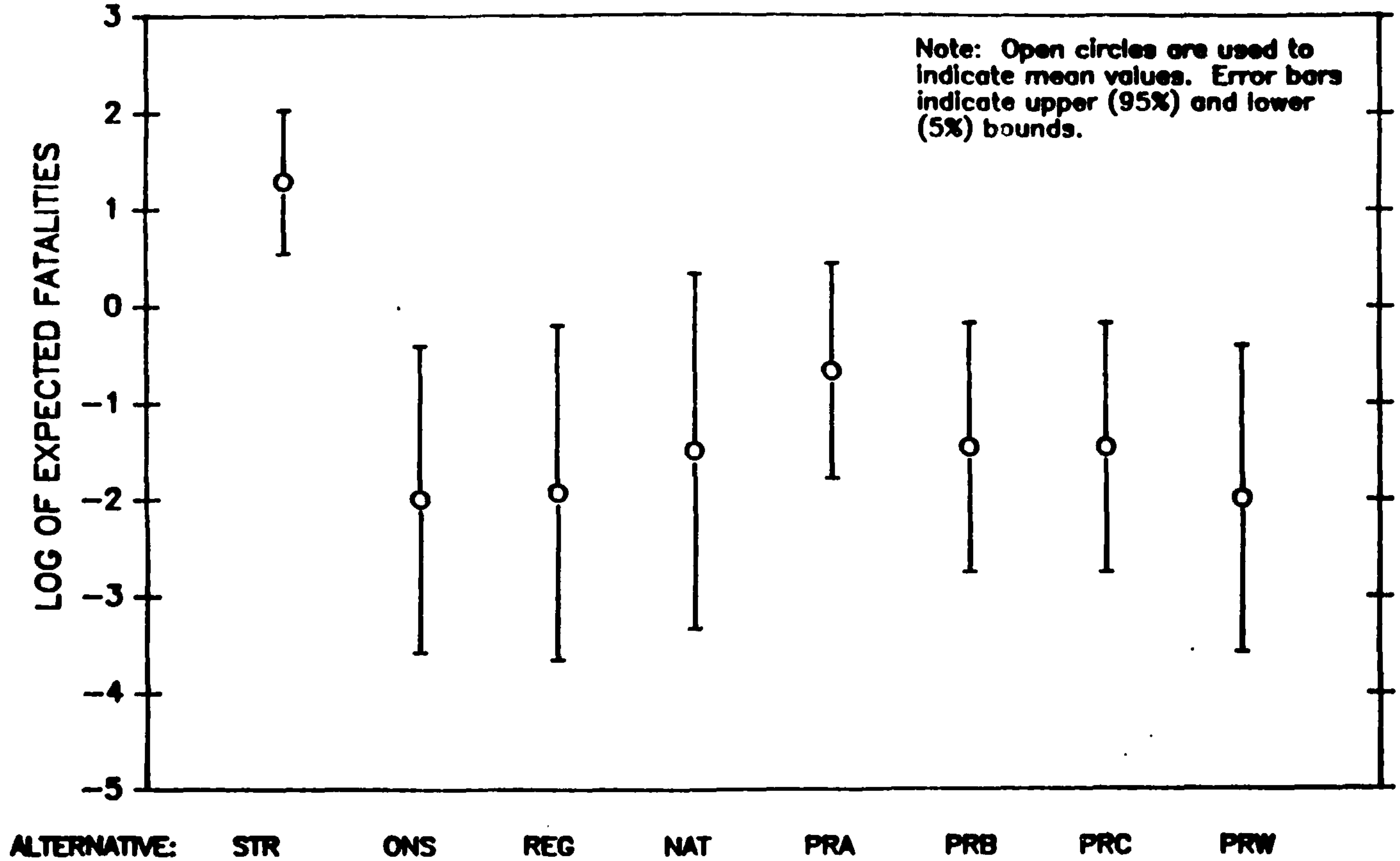


FIGURE 25

SOCIETAL RISK (EXPECTED FATALITIES)
FOR EIGHT PROGRAMMATIC ALTERNATIVES
- UNMITIGATED -

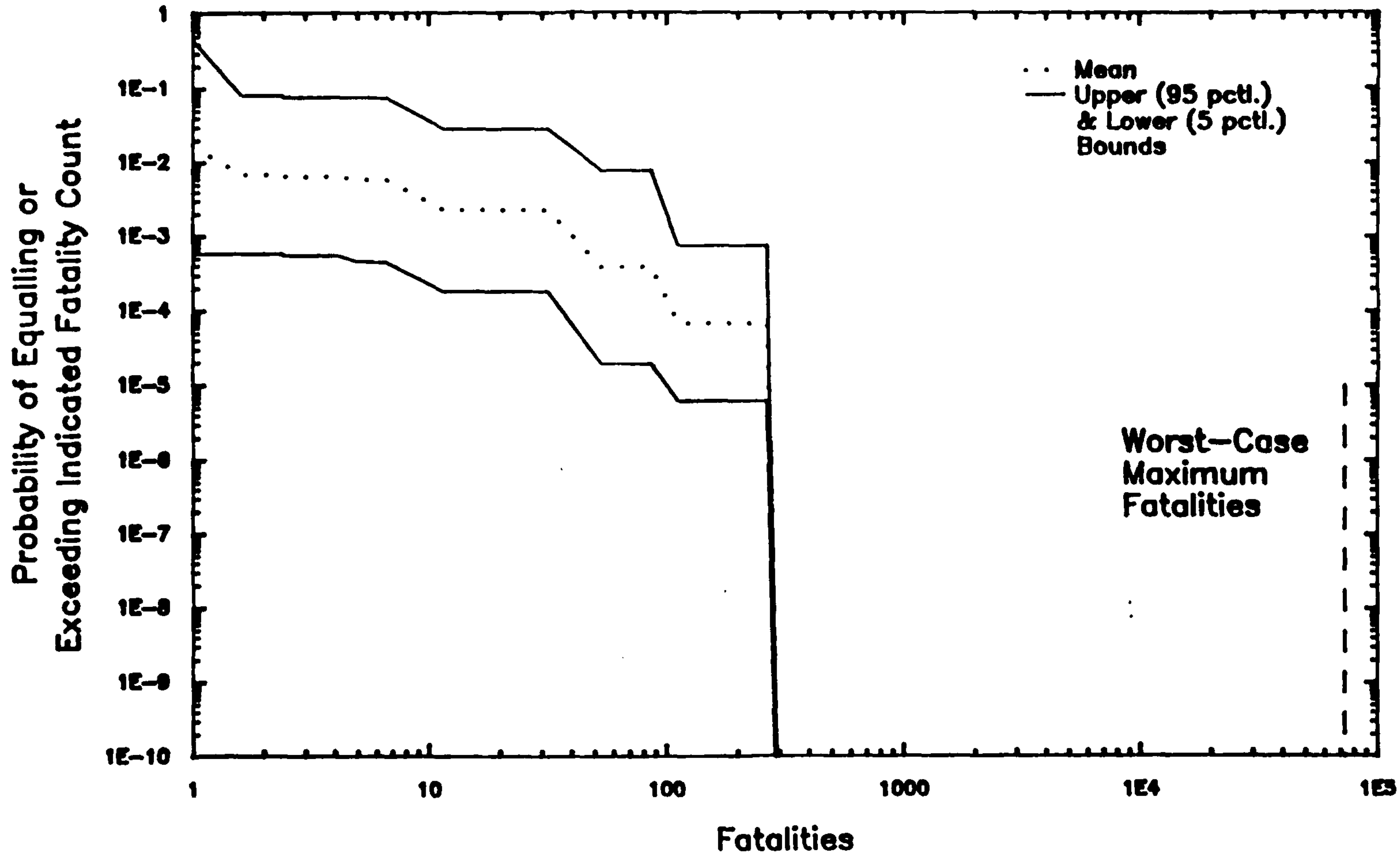


FIGURE 26

SOCIETAL RISK FOR PROGRAMMATIC ALTERNATIVE: PRA PARTIAL RELOCATION: APG & LBAD TO TEAD BY AIR (C5)

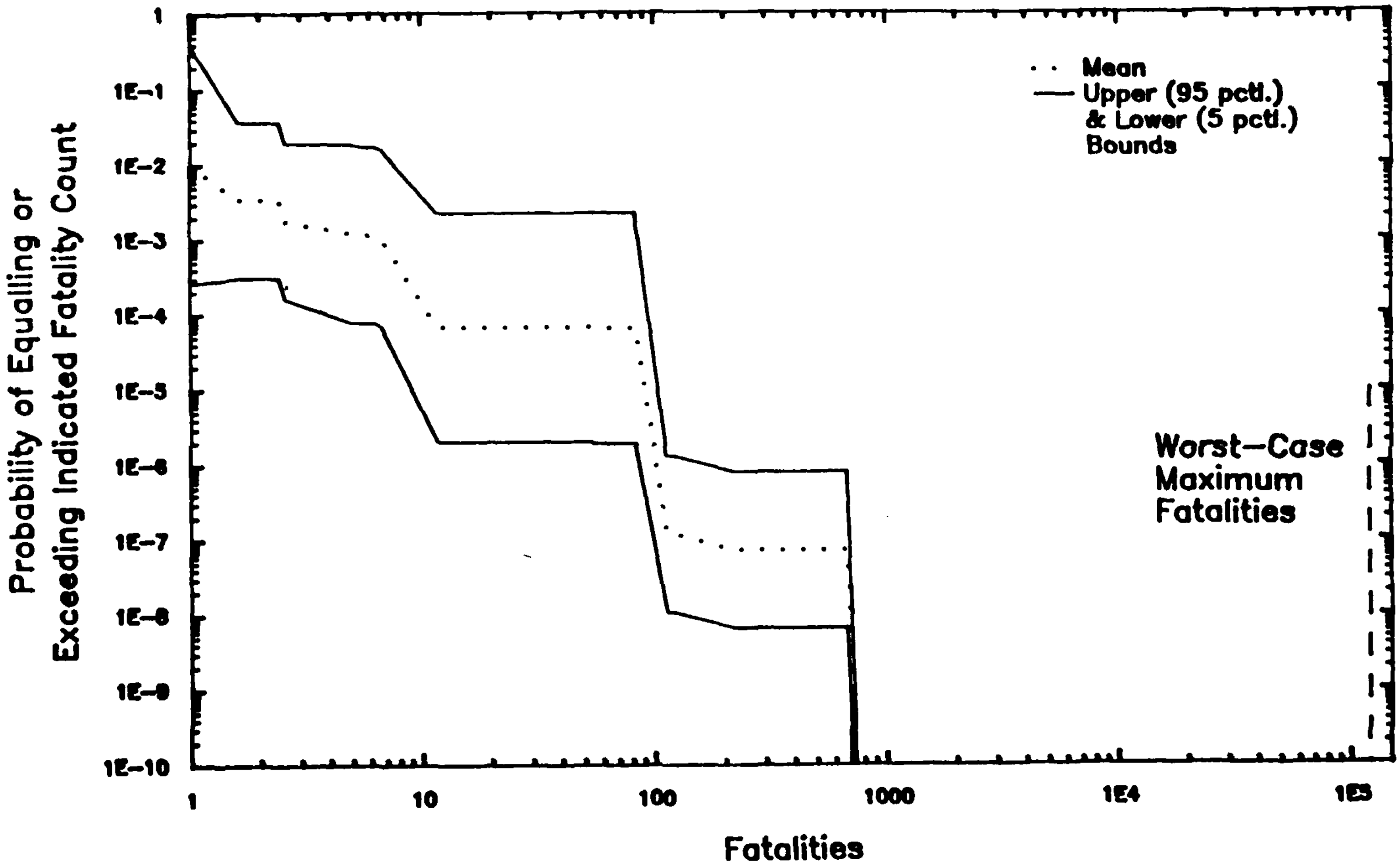


FIGURE 27

SOCIETAL RISK FOR PROGRAMMATIC ALTERNATIVE: PRC
PARTIAL RELOCATION:
APG TO JI BY WATER; LBAD TO TEAD BY AIR (C141)

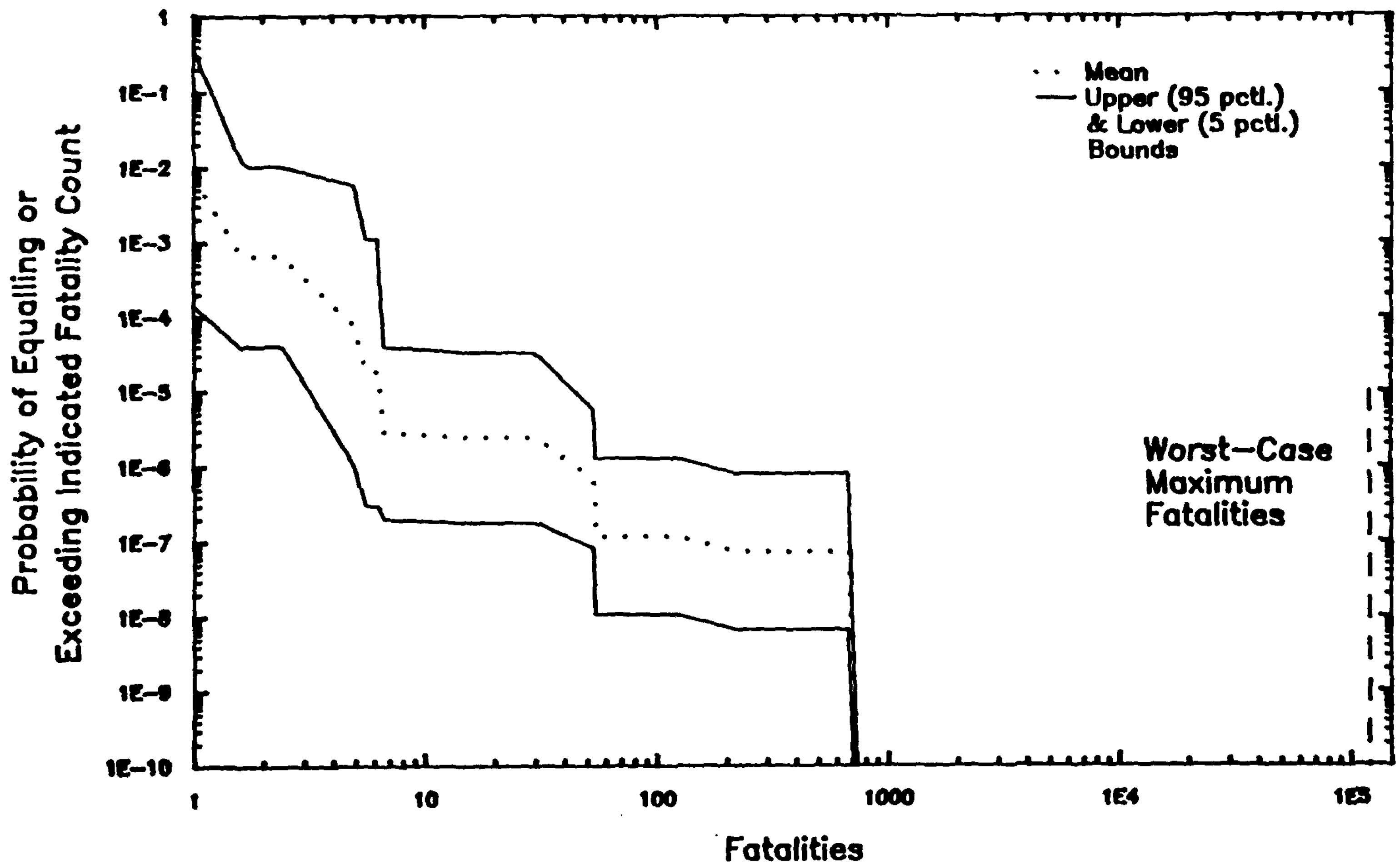


FIGURE 28

SOCIETAL RISK FOR PROGRAMMATIC ALTERNATIVE: PRW
PARTIAL RELOCATION: APG TO JI BY WATER

The most probable accident scenarios (probabilities greater than 10^{-3}) consist of the dunnage incinerator scenarios, the in-flight aircrash scenarios, and certain handling accidents. However, the high probability handling accidents involve no fatalities beyond the military reservation boundary (even though the 'no-deaths' plume length extends beyond the assumed 0.5 km site boundary -- see discussion of this point in section 4.2.2).

The highest consequence accidents (potential fatalities of 335, most-likely conditions) for this alternative are aircraft take-off accidents involving projectiles or rockets containing GB.

Partial Relocation: APG to JI by Water; LBAD to TEAD by Air (C141). Programmatic risk for the partial relocation alternative, PRC, on-site disposal at all sites except for transport of the LBAD stockpiles to TEAD via C141 aircraft, and transport of the APG stockpile to JI by water, is shown by the risk curve in Figure 27. Of total risk, 70 percent is due to off-site transportation and 27 percent results from plant operations. Accidents involving rockets contribute 77 percent of total risk. Accidents along the transportation corridor account for 46 percent of total risk for this alternative.

The highest consequence accidents for this alternative (909 potential fatalities) are due to aircraft crashes onto the LASH vessel while at anchorage, resulting in an uncontained fire.

The probability of one or more fatalities for this alternative is also approximately 10^{-2}.

Partial Relocation: APG to JI by Water. Programmatic risk for the partial relocation alternative, PRW, on-site disposal at all sites except for transport of the APG stockpile to JI by water, is shown by the risk curve in Figure 28. Of total risk, less than 1 percent is due to off-site transportation while the bulk of the risk (92 percent) results from plant operations. Accidents involving rockets contribute 42 percent of total risk; mine-related accidents contribute 25 percent to risk; and, accidents involving bulk containers account for 31 percent of the total.

The highest consequence accident for this alternative (909 potential fatalities), as for the partial relocation alternative, PRC, is due to small aircraft crashes onto the LASH vessel while at rest, resulting in an uncontained fire.

The probability of one or more fatalities for this alternative is approximately 10^{-2}.

3.3 Location-Specific Risk

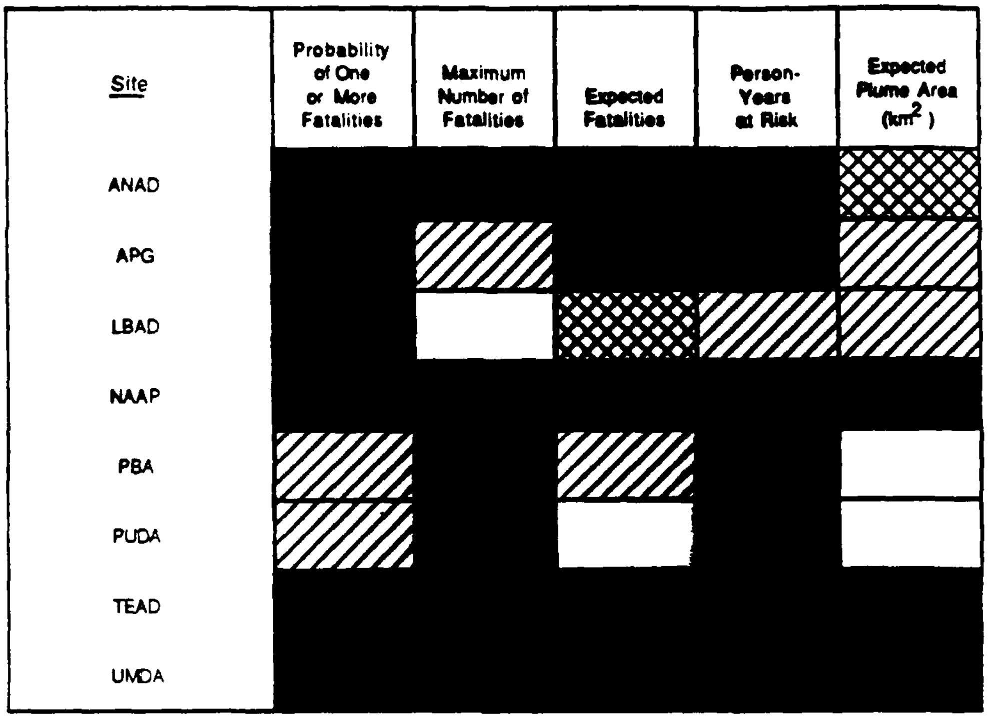
In this section, the distribution of risk according to location (storage/disposal -- i.e., "fixed" -- sites and transportation corridors) is presented by means of the 'pictogram' display of the major risk parameters as shown in Figures 29 through 70. The first 15 pictograms, Figures 29 through 43, compare the risk measures for each of the five FPEIS disposal alternatives at each of the eight sites for the unmitigated case plus two levels of mitigation. Figures 44 through 46 present the risk to the transportation corridor populations (which is not affected by the proposed mitigation measures) for the three alternatives involving off-site transport of the stockpile. Figures 47 through 70 present the 'pictogram' displays of risk measures for each of the eight sites and for the unmitigated case plus two levels of mitigation. Although the relevant values (shadings) in Figures 29 through 43 are identical to those for Figures 47 through 70, the informa' on is presented on a site-by-site basis for the latter figures to facilitate comparison of risks at a site for the different alternatives. The reader should note that all figures displaying site risk do not incorporate risks along a transportation corridors. (The corresponding 'pictogram' for all locations combined was presented as Figures 8 through 10, depending on mitigation level.)

In addition, risk to an individual -- a meaningful concept only when a specific location is considered -- is discussed, in section 3.4, in terms of both the probability of an individual's death at a given distance from a fixed site or transportation corridor (equal to **maximum individual risk** when that given distance is the minimum), the **maximum lethal distance** from a potential accident site, and the individual's '**time-at-risk**'.

3.3.1 Distribution of Programmatic Risk by Location

In addition to the differences in overall programmatic risk among the disposal alternatives, as presented in section 3.2, there are major differences in how that risk (as measured by **expected fatalities**) is distributed among the affected population groups. The pictograms supporting this discussion are those presented in Figures 29 through 46. In this regard, we note the following:

- For continued storage, the risk is borne primarily by two sites: NAAP with 85 percent of the total, and UMDA with 14 percent; when mitigation is introduced, the total program risk burden becomes somewhat more evenly shared, with NAAP dropping to 75 percent of the total (reduced) program risk and APG and UMDA carrying equal portions of the remainder of the risk; the risk of continued storage is relatively insignificant at the remaining five sites. When air-space restrictions are introduced (mitigation, revision 2), the major beneficiary is the APG area, with its contribution to



Numerical Equivalents

Legend Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-3}$	>10,000	$>10^{-2}$	$>10^{6}$	$>10^{-2}$
		10^{-4} - 10^{-3}	5000 - 10,000	10^{-3} - 10^{-2}	10^{5} - 10^{6}	10^{-3} - 10^{-2}
		10^{-5} - 10^{-4}	1000 - 5000	10^{-4} - 10^{-3}	10^{4} - 10^{5}	10^{-4} - 10^{-3}
Lower		$<10^{-5}$	<1000	$<10^{-4}$	$<10^{4}$	$<10^{-4}$

FIGURE 29

SITE-SPECIFIC COMPARISON OF RISK FOR CONTINUED STORAGE (STR) 25 YEARS

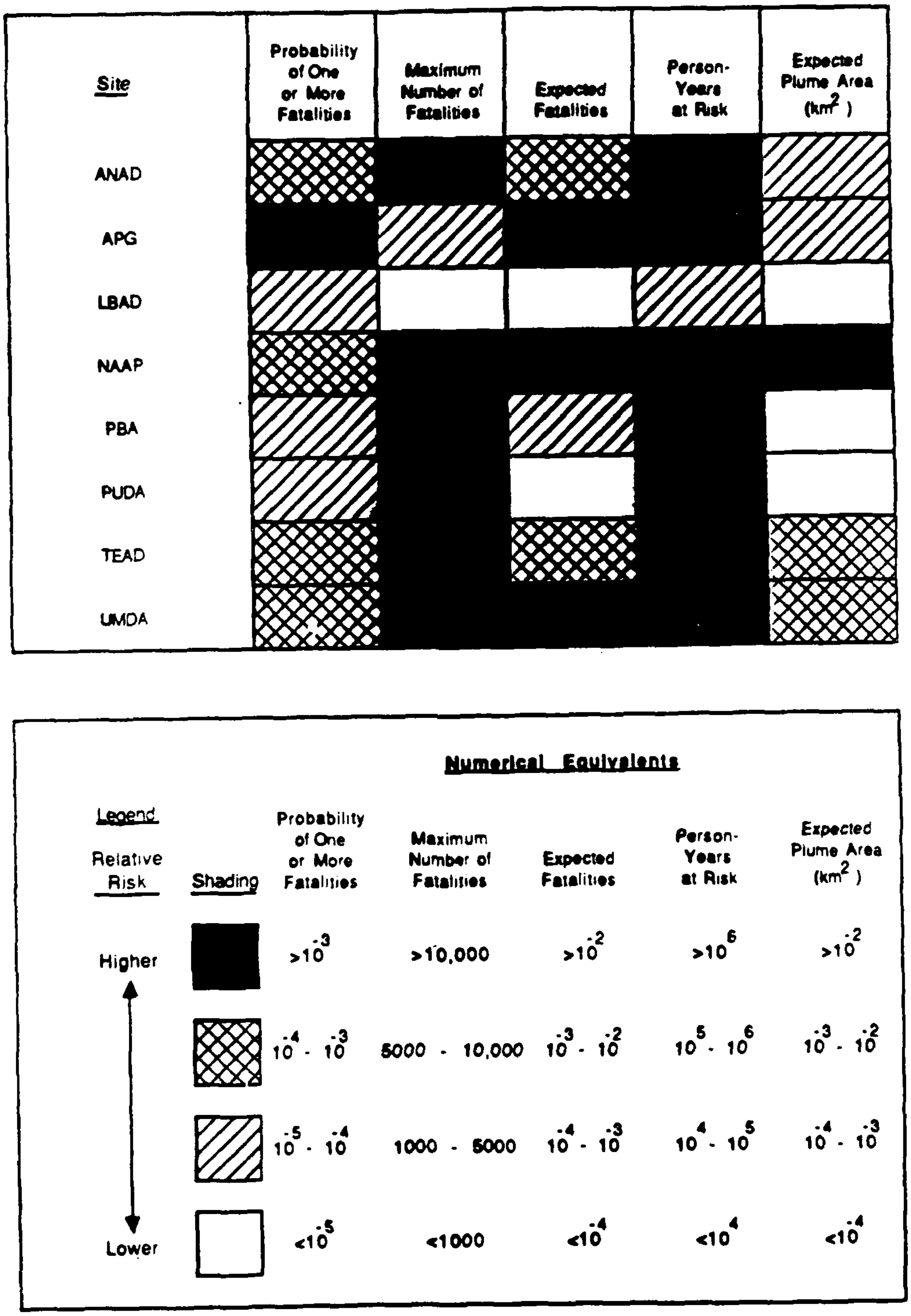


FIGURE 30

RISK WITH MITIGATION (REV. 1): SITE-SPECIFIC COMPARISON FOR CONTINUED STORAGE (STR) 25 YEARS

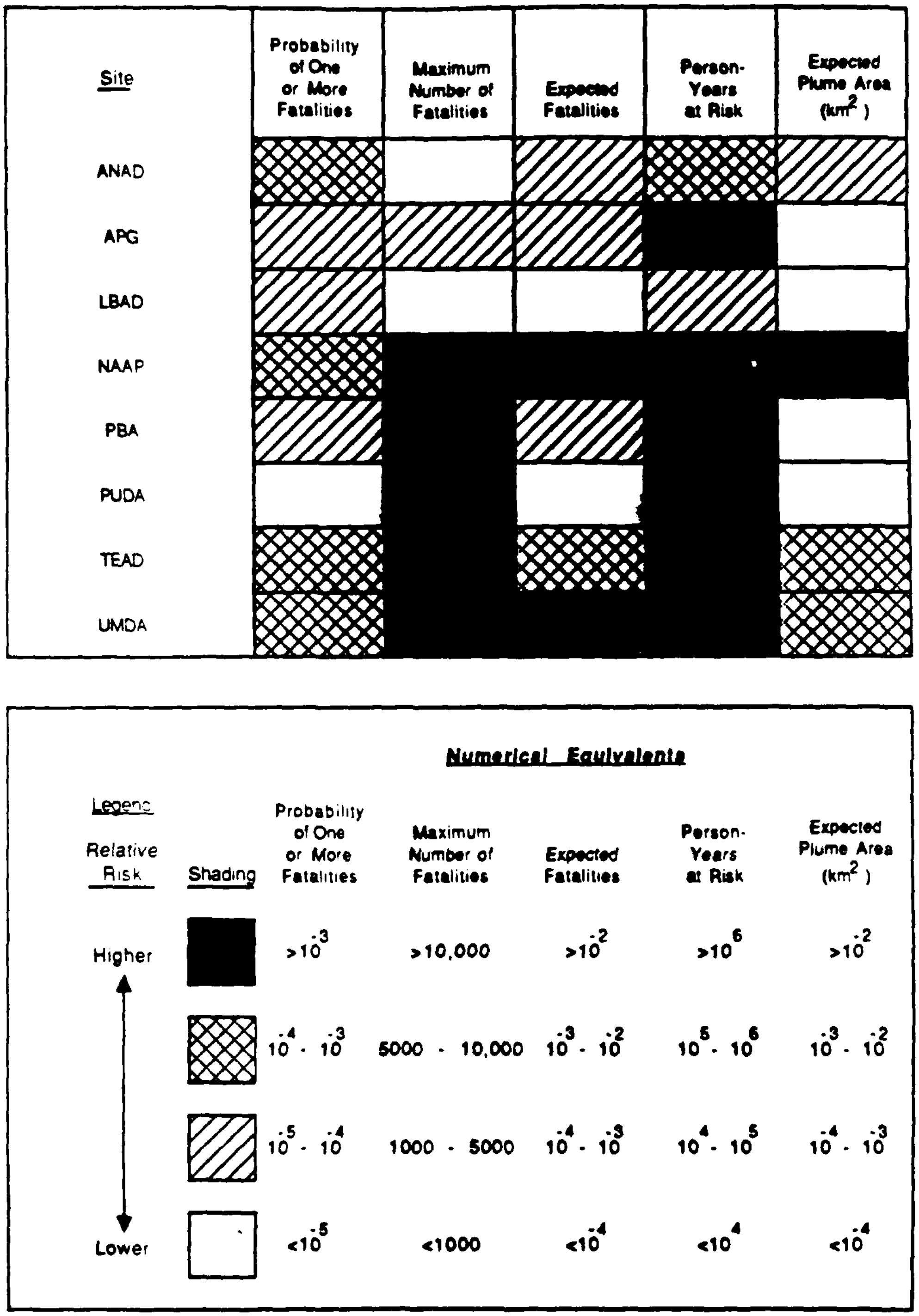
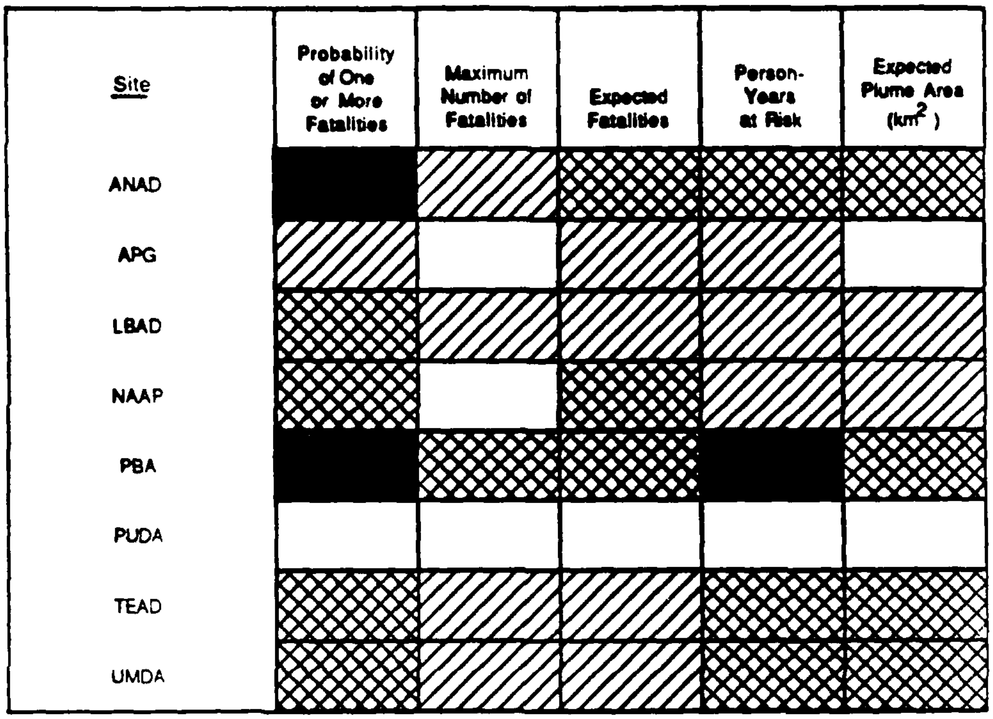


FIGURE 31

RISK WITH MITIGATION (REV. 2): SITE-SPECIFIC COMPARISON FOR CONTINUED STORAGE (STR) 25 YEARS



Legend

Numerical Equivalents

Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-3}$	>10,000	$>10^{-2}$	$>10^{6}$	$>10^{-2}$
		10^{-4} - 10^{-3}	5000 - 10,000	10^{-3} - 10^{-2}	10^{5} - 10^{6}	10^{-3} - 10^{-2}
		10^{-5} - 10^{-4}	1000 - 5000	10^{-4} - 10^{-3}	10^{4} - 10^{5}	10^{-4} - 10^{-3}
Lower		$<10^{-5}$	<1000	$<10^{-4}$	$<10^{4}$	$<10^{-4}$

FIGURE 32

SITE-SPECIFIC COMPARISON OF RISK FOR ON-SITE DISPOSAL (ONS)

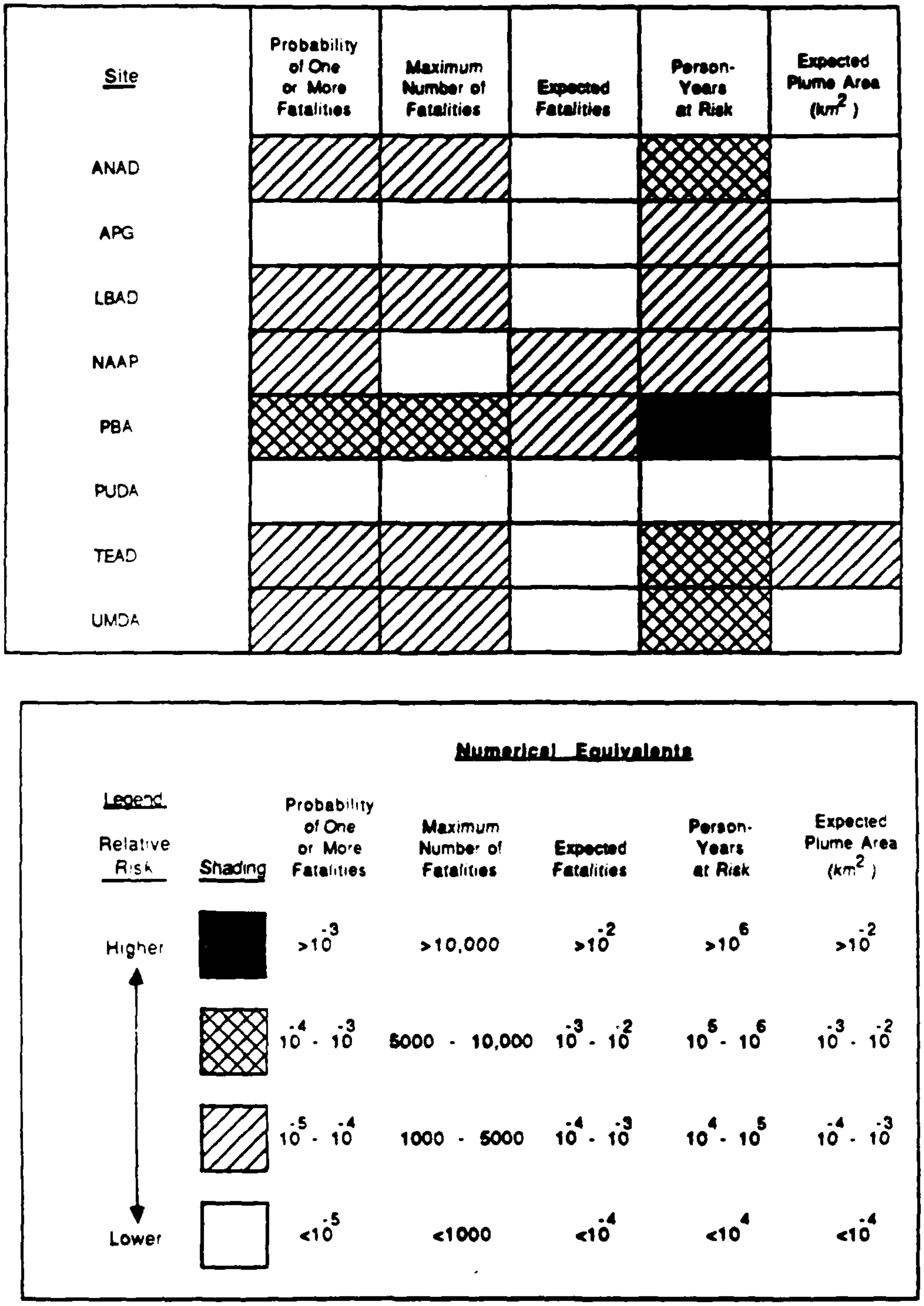


FIGURE 33

RISK WITH MITIGATION (REV. 1): SITE-SPECIFIC COMPARISON FOR ON-SITE DISPOSAL (ONS)

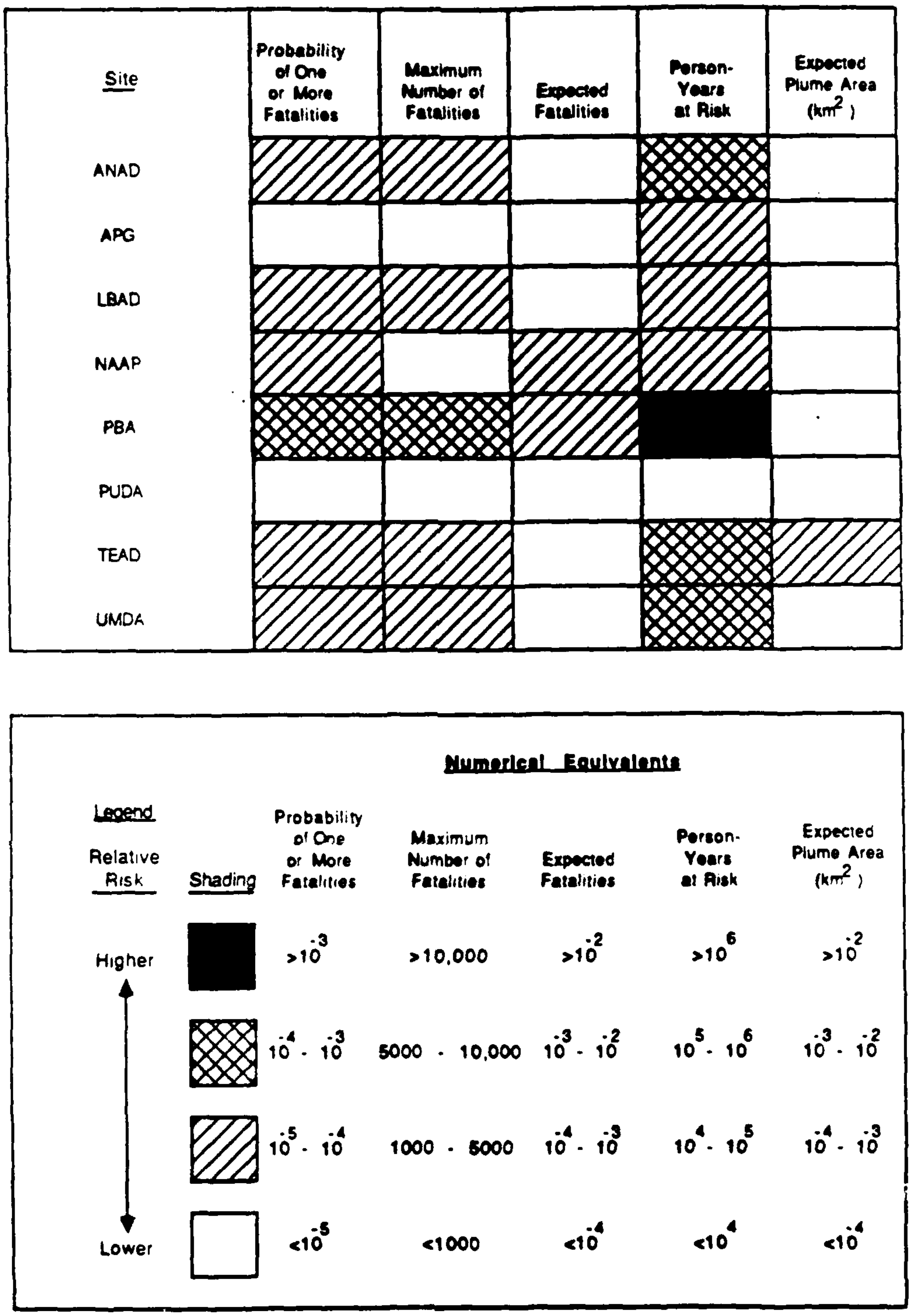


FIGURE 34

RISK WITH MITIGATION (REV. 2): SITE-SPECIFIC COMPARISON FOR ON-SITE DISPOSAL (ONS)

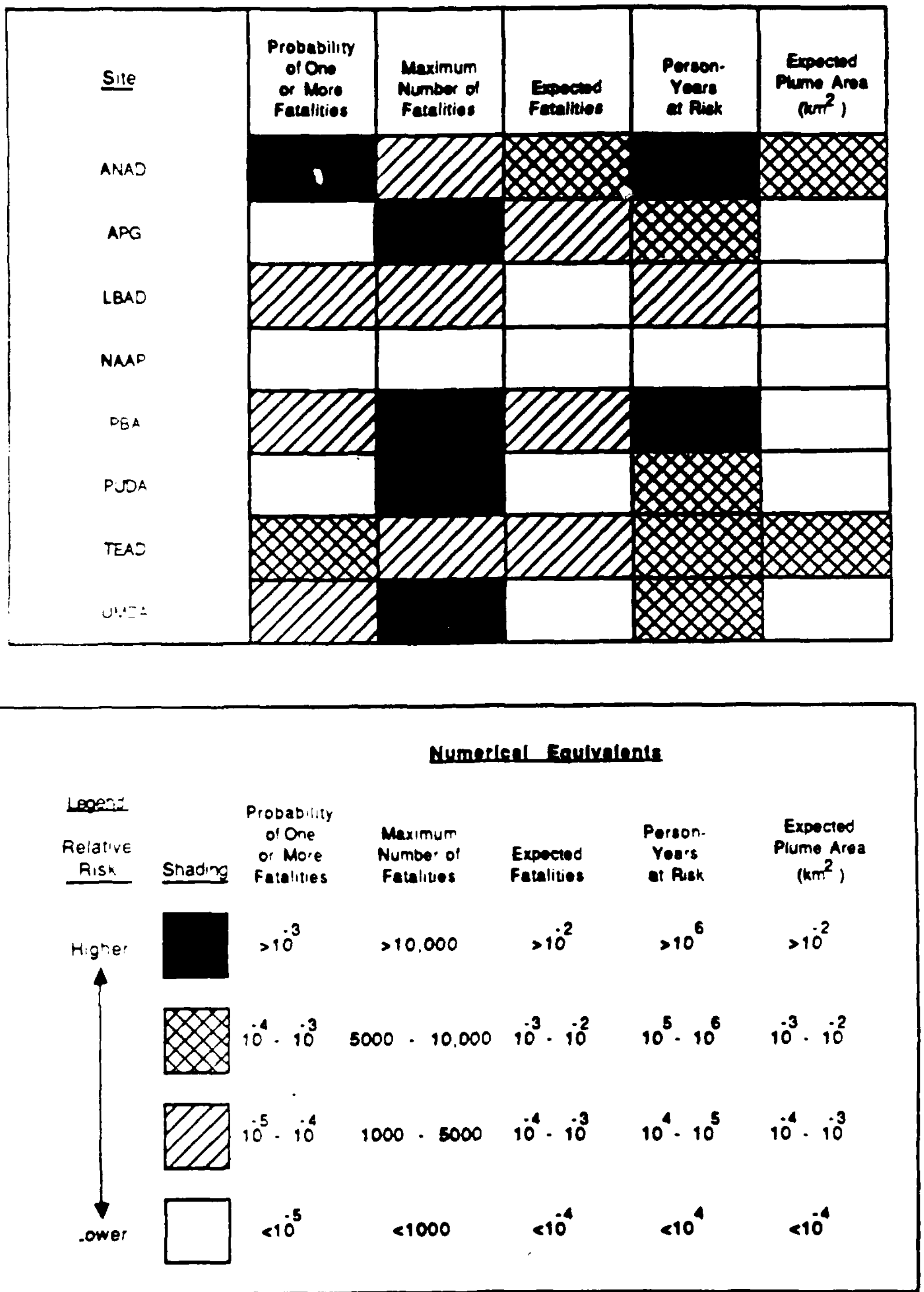
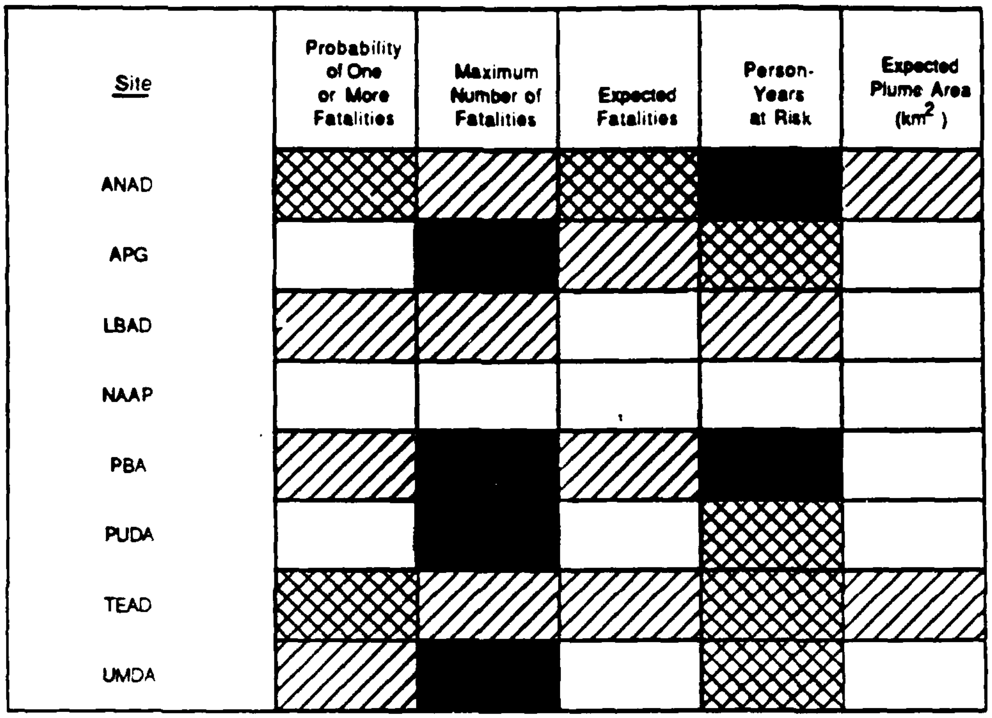


FIGURE 35

SITE-SPECIFIC COMPARISON OF RISK FOR REGIONAL DISPOSAL (REG)

(Risk along transportation corridors not included)



Numerical Equivalents

Legend Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-3}$	>10,000	$>10^{-2}$	$>10^{6}$	$>10^{-2}$
		$10^{-4} - 10^{-3}$	5000 - 10,000	$10^{-3} - 10^{-2}$	$10^{5} - 10^{6}$	$10^{-3} - 10^{-2}$
		$10^{-5} - 10^{-4}$	1000 - 5000	$10^{-4} - 10^{-3}$	$10^{4} - 10^{5}$	$10^{-4} - 10^{-3}$
Lower		$<10^{-5}$	<1000	$<10^{-4}$	$<10^{4}$	$<10^{-4}$

FIGURE 36

RISK WITH MITIGATION (REV. 1): SITE-SPECIFIC COMPARISON FOR REGIONAL DISPOSAL (REG)

(Risk along transportation corridors not included)

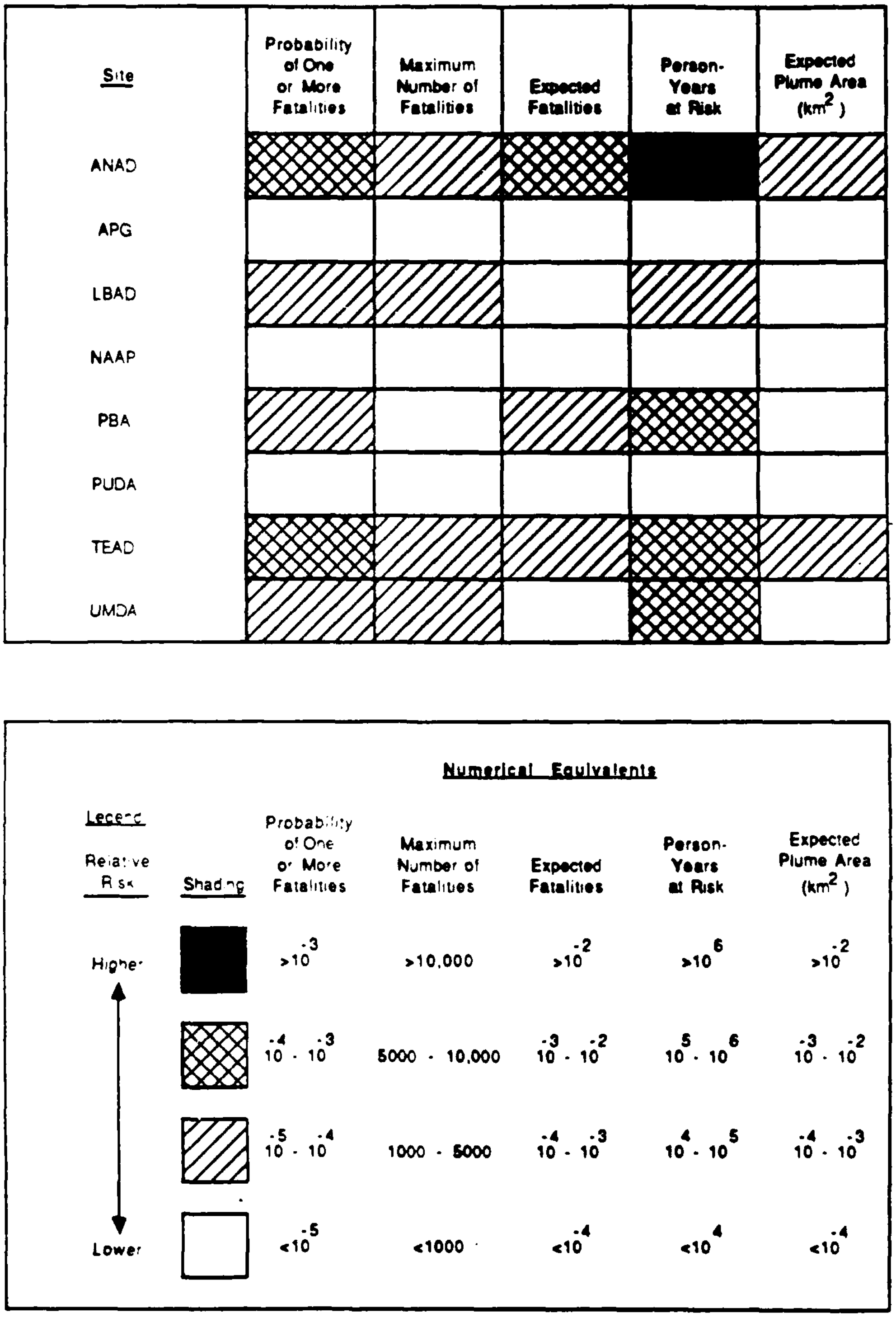
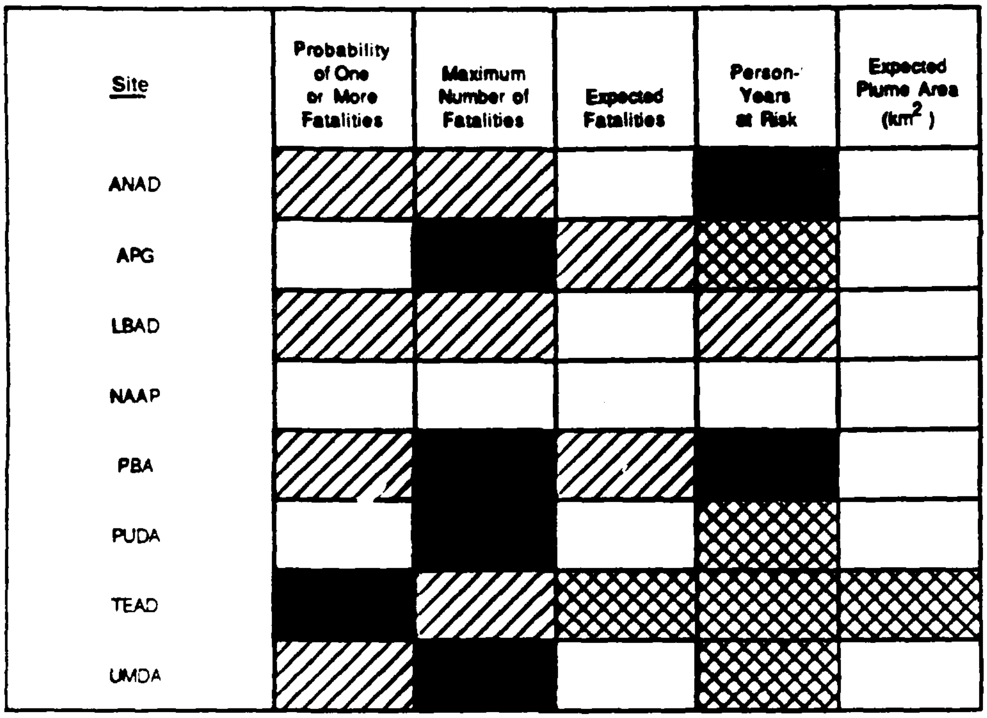


FIGURE 37

RISK WITH MITIGATION (REV. 2): SITE-SPECIFIC COMPARISON FOR REGIONAL DISPOSAL (REG)

(Risk along transportation corridors not included)



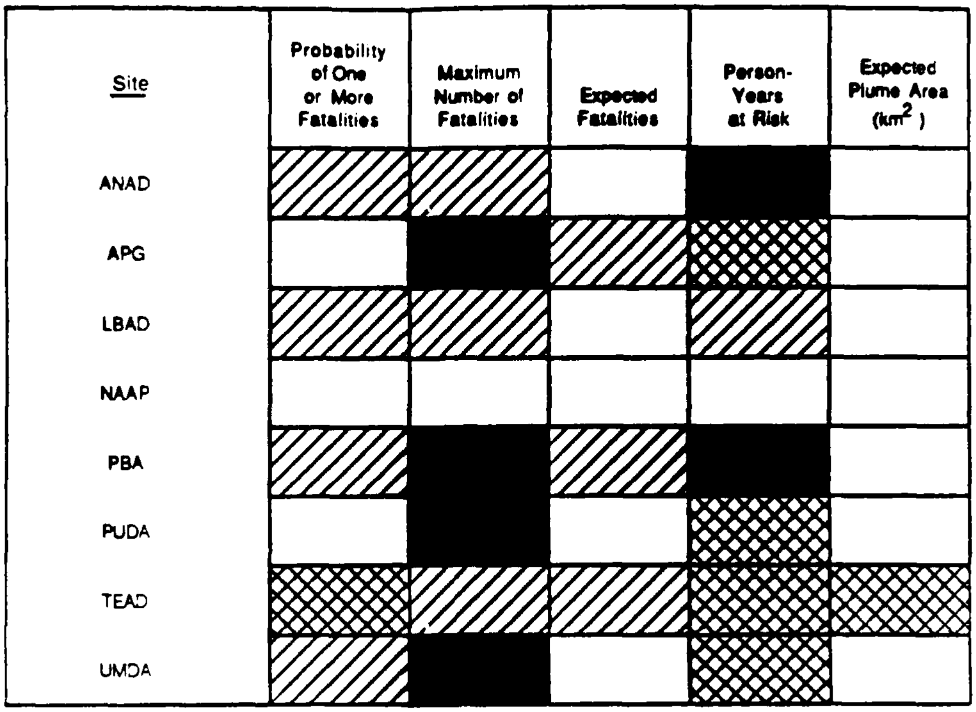
Numerical Equivalents

Legend Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-3}$	>10,000	$>10^{-2}$	$>10^{6}$	$>10^{-2}$
		$10^{-4} - 10^{-3}$	5000 - 10,000	$10^{-3} - 10^{-2}$	$10^{5} - 10^{6}$	$10^{-3} - 10^{-2}$
		$10^{-5} - 10^{-4}$	1000 - 5000	$10^{-4} - 10^{-3}$	$10^{4} - 10^{5}$	$10^{-4} - 10^{-3}$
Lower		$<10^{-5}$	<1000	$<10^{-4}$	$<10^{4}$	$<10^{-4}$

FIGURE 38

SITE-SPECIFIC COMPARISON OF RISK FOR NATIONAL DISPOSAL (NAT)

(Risk along transportation corridors not included)



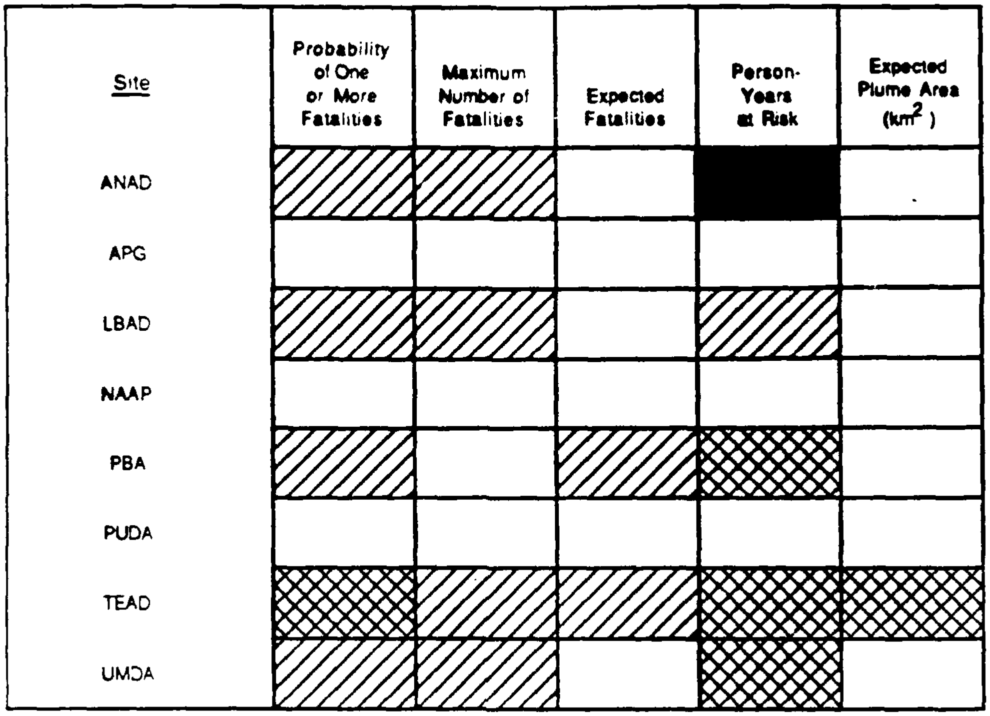
Numerical Equivalents

Legend: Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-3}$	>10,000	$>10^{-2}$	$>10^{6}$	$>10^{-2}$
		10^{-4} - 10^{-3}	5000 - 10,000	10^{-3} - 10^{-2}	10^{5} - 10^{6}	10^{-3} - 10^{-2}
		10^{-5} - 10^{-4}	1000 - 5000	10^{-4} - 10^{-3}	10^{4} - 10^{5}	10^{-4} - 10^{-3}
Lower		$<10^{-5}$	<1000	$<10^{-4}$	$<10^{4}$	$<10^{-4}$

FIGURE 39

RISK WITH MITIGATION (REV. 1): SITE-SPECIFIC COMPARISON FOR NATIONAL DISPOSAL (NAT)

(Risk along transportation corridors not included)



Numerical Equivalents

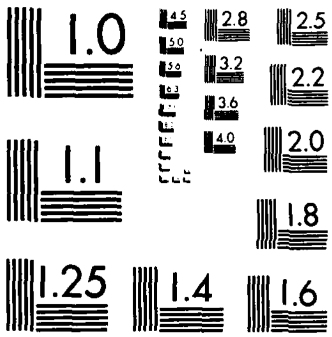
Legend: Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-3}$	>10,000	$>10^{-2}$	$>10^{6}$	$>10^{-2}$
		$10^{-4} - 10^{-3}$	5000 - 10,000	$10^{-3} - 10^{-2}$	$10^{5} - 10^{6}$	$10^{-3} - 10^{-2}$
		$10^{-5} - 10^{-4}$	1000 - 5000	$10^{-4} - 10^{-3}$	$10^{4} - 10^{5}$	$10^{-4} - 10^{-3}$
Lower		$<10^{-5}$	<1000	$<10^{-4}$	$<10^{4}$	$<10^{-4}$

FIGURE 40

RISK WITH MITIGATION (REV. 2): SITE-SPECIFIC COMPARISON FOR NATIONAL DISPOSAL (NAT)

(Risk along transportation corridors not included)

AD-A216 734 RISK ANALYSIS IN SUPPORT OF THE CHEMICAL STOCKPILE 2/3
DISPOSAL PROGRAM VOLUM (U) MITRE CORP MCLEAN VA CIVIL
SYSTEMS DIV W E FRAIZE ET AL 17 DEC 87
UNCLASSIFIED MTR-87W00230-VOL-1 SAPEO-CDE-IS-87014-VOL-1 F/G 15/6 3 NL


1.0
4.5
5.0
5.6
6.3
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

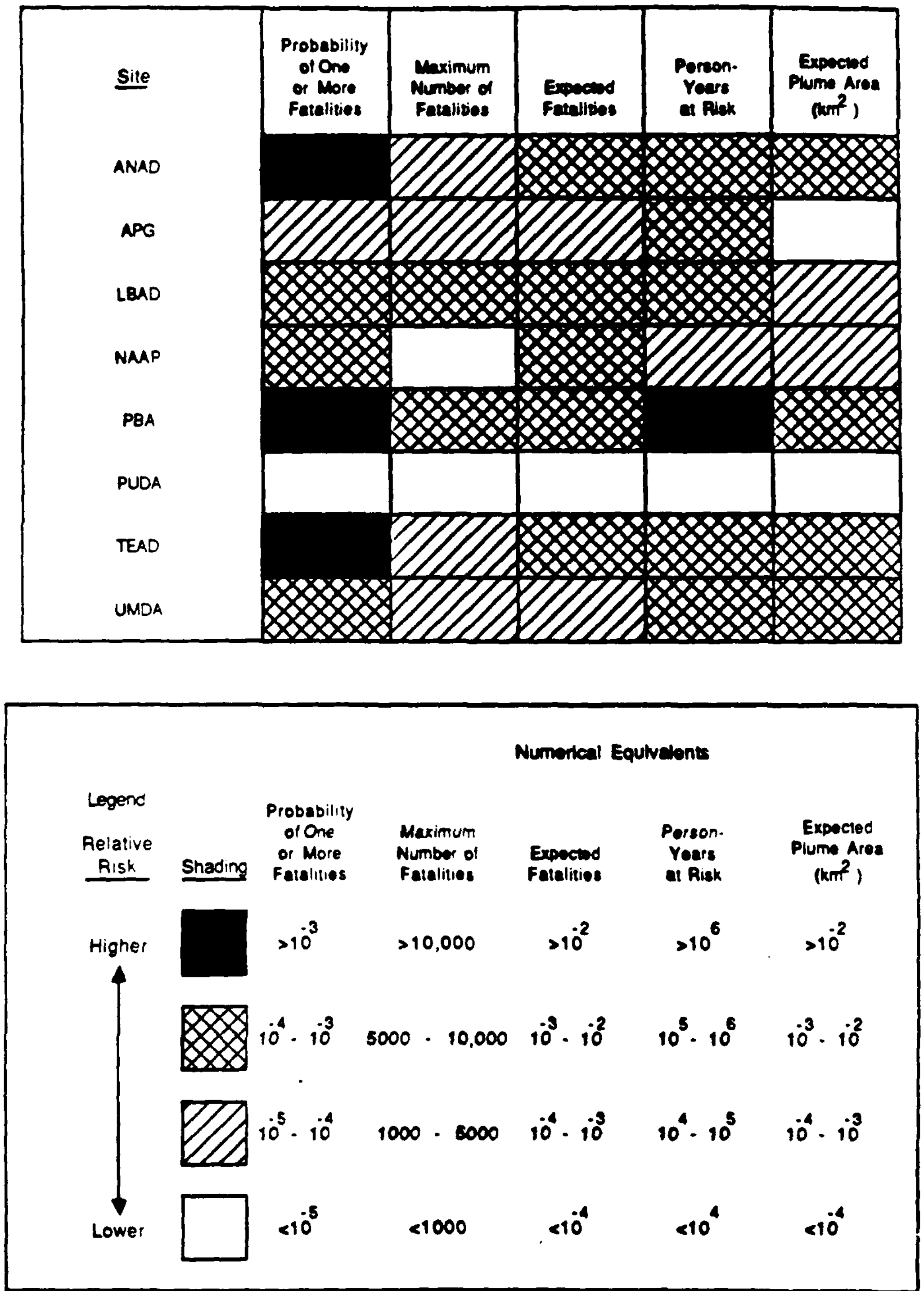


FIGURE 41

SITE-SPECIFIC COMPARISON OF RISK FOR PARTIAL RELOCATION (PR)

(Risk along transportation corridors not included)

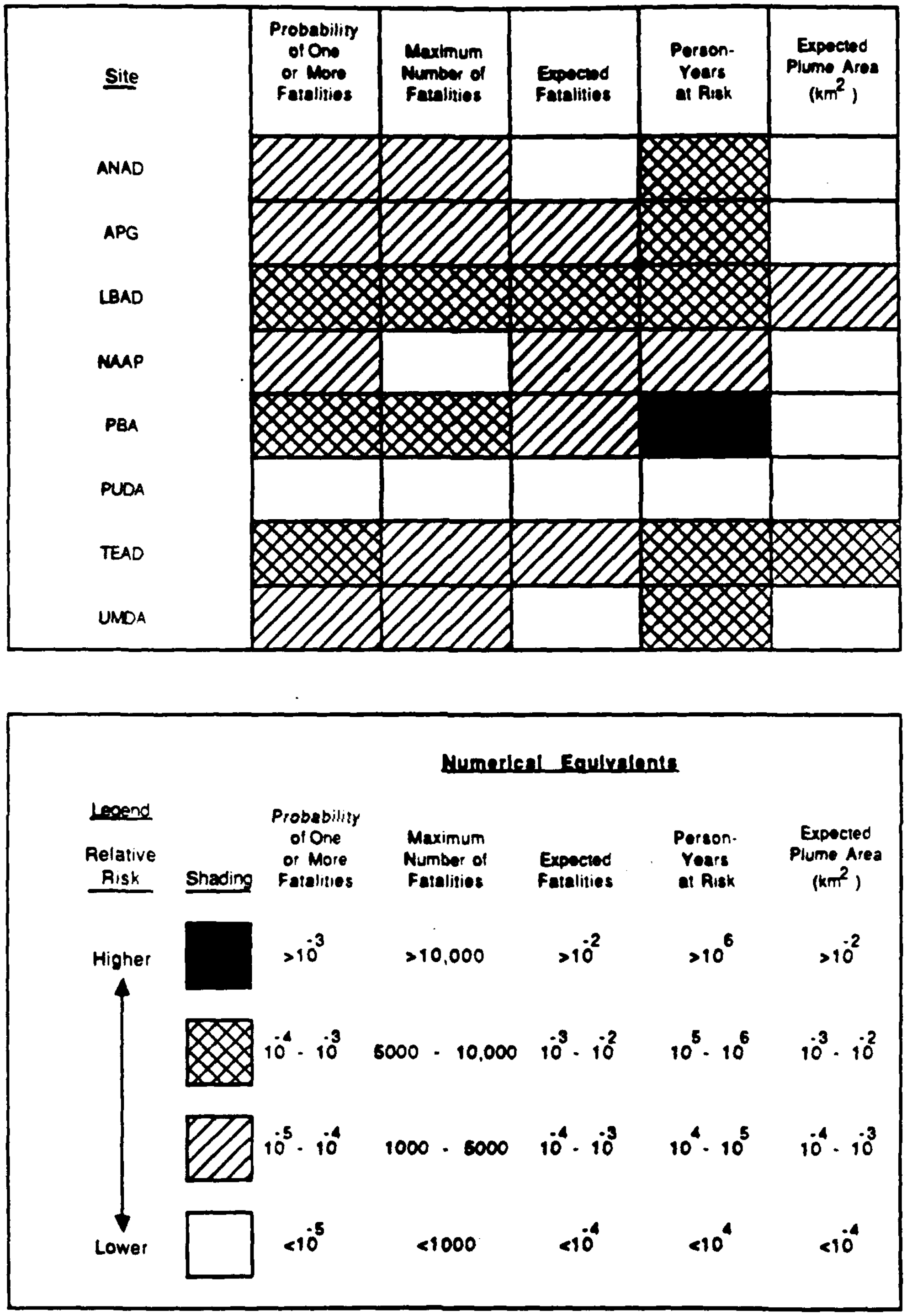


FIGURE 42

RISK WITH MITIGATION (REV. 1): SITE-SPECIFIC COMPARISON FOR PARTIAL RELOCATION (PR)

(Risk along transportation corridors not included)

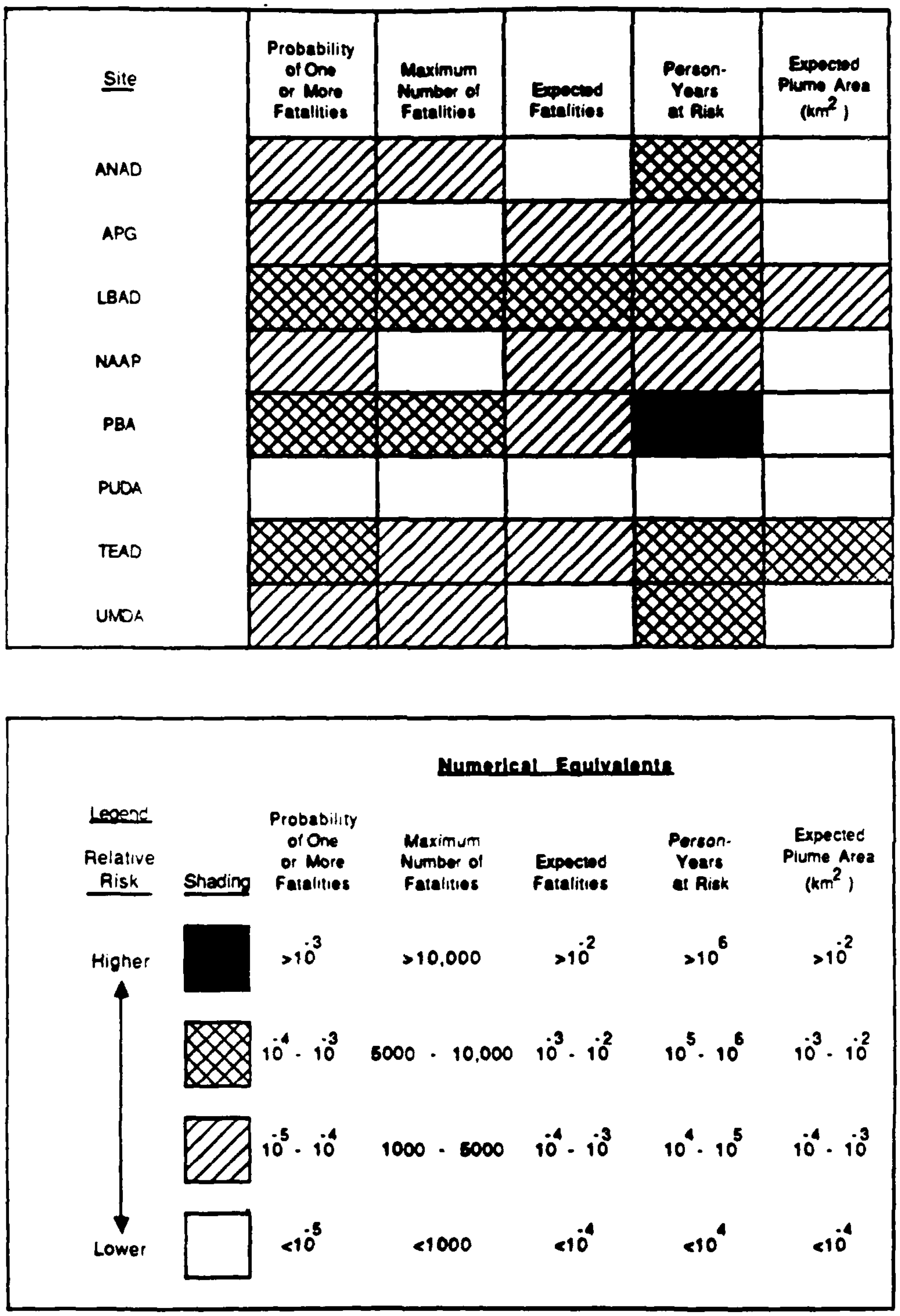
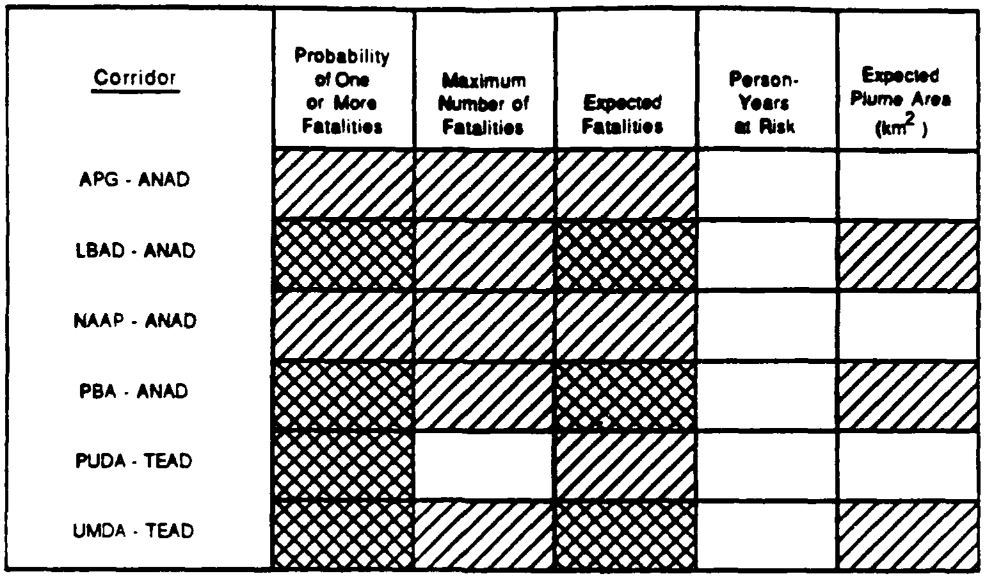


FIGURE 43

RISK WITH MITIGATION (REV. 2): SITE-SPECIFIC COMPARISON FOR PARTIAL RELOCATION (PR)

(Risk along transportation corridors not included)



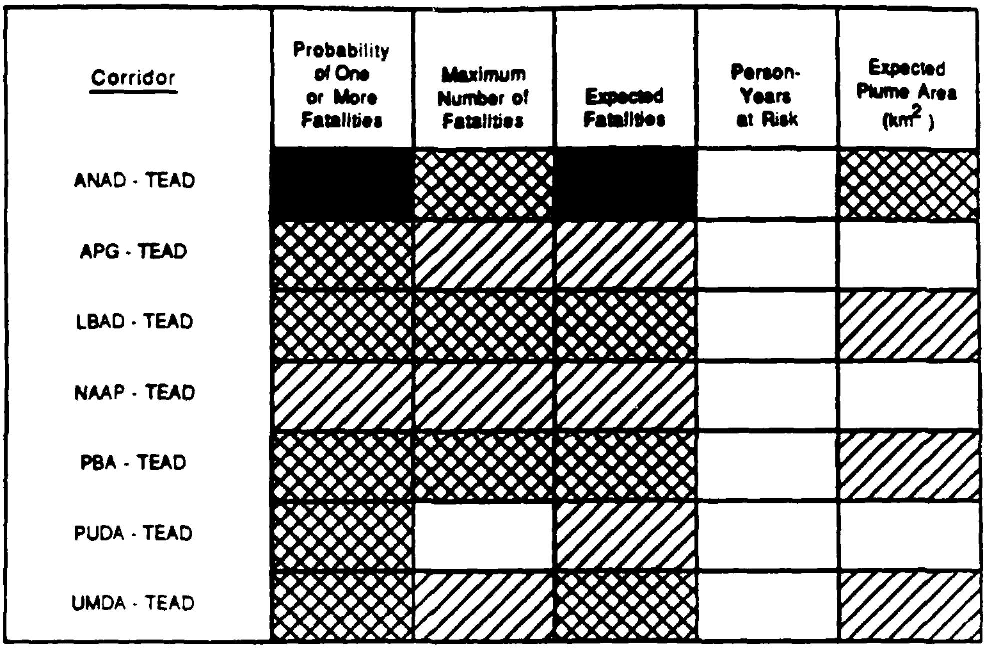
Numerical Equivalents

Legend

Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-3}$	>10,000	$>10^{-2}$	$>10^{6}$	$>10^{-2}$
		10^{-4} - 10^{-3}	5000 - 10,000	10^{-3} - 10^{-2}	10^{5} - 10^{6}	10^{-3} - 10^{-2}
		10^{-5} - 10^{-4}	1000 - 5000	10^{-4} - 10^{-3}	10^{4} - 10^{5}	10^{-4} - 10^{-3}
Lower		$<10^{-5}$	<1000	$<10^{-4}$	$<10^{4}$	$<10^{-4}$

FIGURE 44

RISK ALONG RAIL TRANSPORTATION CORRIDORS FOR REGIONAL DISPOSAL - ALL MITIGATION LEVELS -



Numerical Equivalents

Legend: Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-3}$	>10,000	$>10^{-2}$	$>10^{6}$	$>10^{-2}$
		$10^{-4} - 10^{-3}$	5000 - 10,000	$10^{-3} - 10^{-2}$	$10^{5} - 10^{6}$	$10^{-3} - 10^{-2}$
		$10^{-5} - 10^{-4}$	1000 - 5000	$10^{-4} - 10^{-3}$	$10^{4} - 10^{5}$	$10^{-4} - 10^{-3}$
Lower		$<10^{-5}$	<1000	$<10^{-4}$	$<10^{4}$	$<10^{-4}$

FIGURE 45

RISK ALONG RAIL TRANSPORTATION CORRIDORS FOR NATIONAL DISPOSAL - ALL MITIGATION LEVELS -

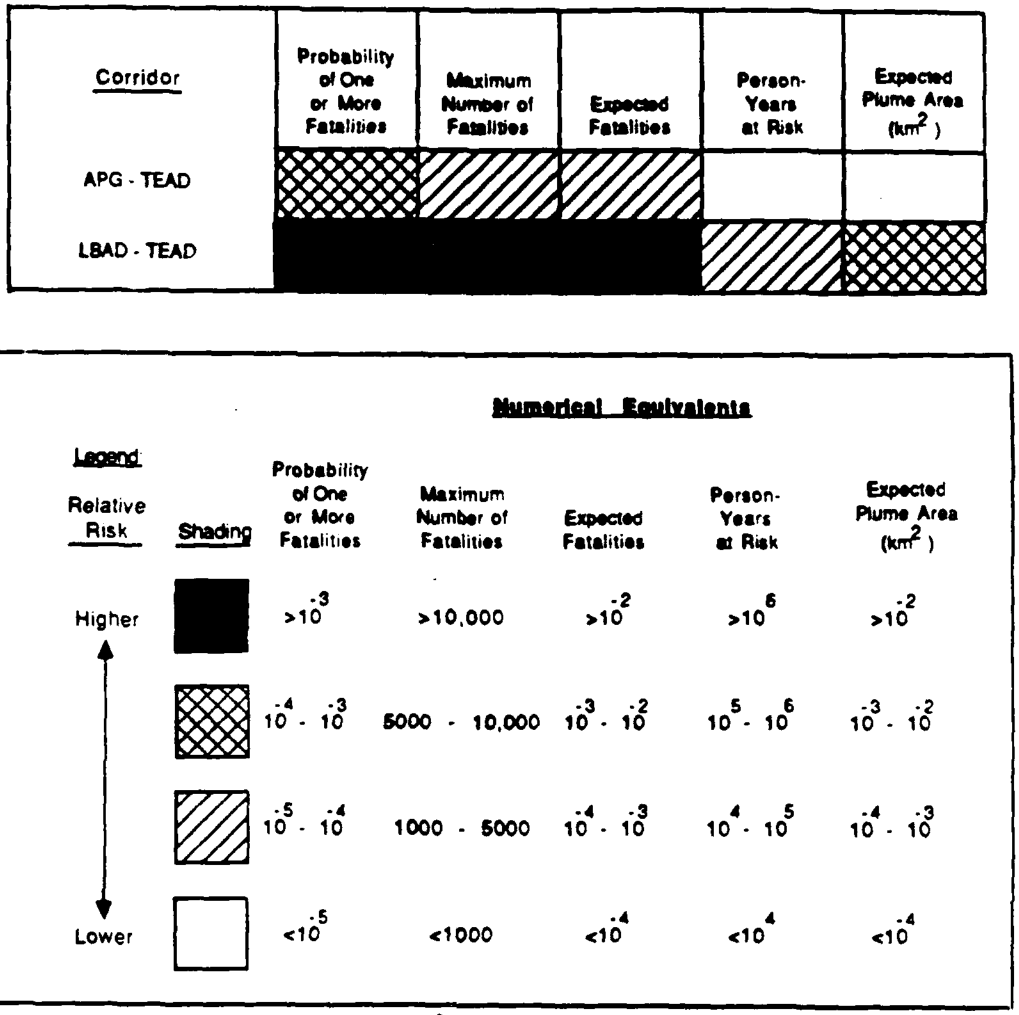
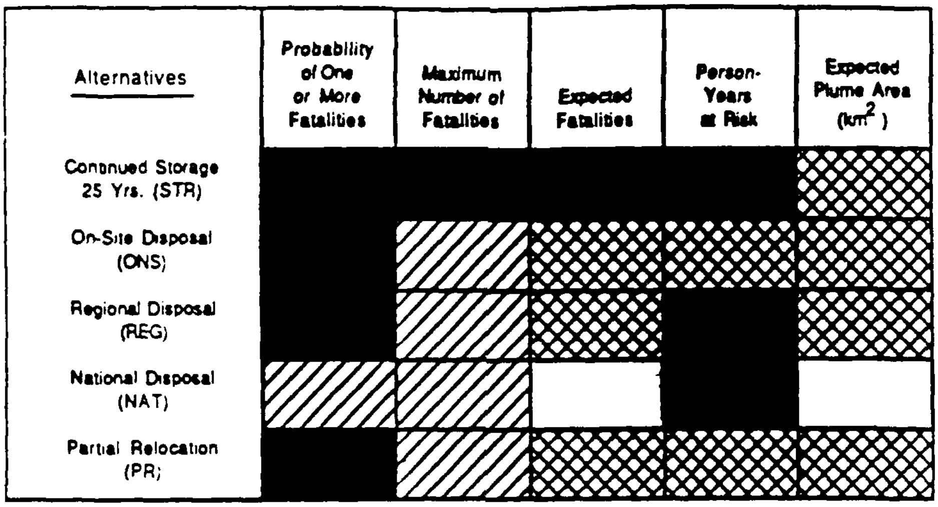


FIGURE 46

RISK ALONG AIR TRANSPORTATION CORRIDOR FOR PARTIAL RELOCATION DISPOSAL - ALL MITIGATION LEVELS -



Numerical Equivalents

Legend: Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-3}$	>10,000	$>10^{-2}$	$>10^{6}$	$>10^{-2}$
		$10^{-4} - 10^{-3}$	5000 - 10,000	$10^{-3} - 10^{-2}$	$10^{5} - 10^{6}$	$10^{-3} - 10^{-2}$
		$10^{-5} - 10^{-4}$	1000 - 5000	$10^{-4} - 10^{-3}$	$10^{4} - 10^{5}$	$10^{-4} - 10^{-3}$
Lower		$<10^{-5}$	<1000	$<10^{-4}$	$<10^{4}$	$<10^{-4}$

FIGURE 47

RISK IN THE VICINITY OF ANNISTON ARMY DEPOT (ANAD) FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridors not included)

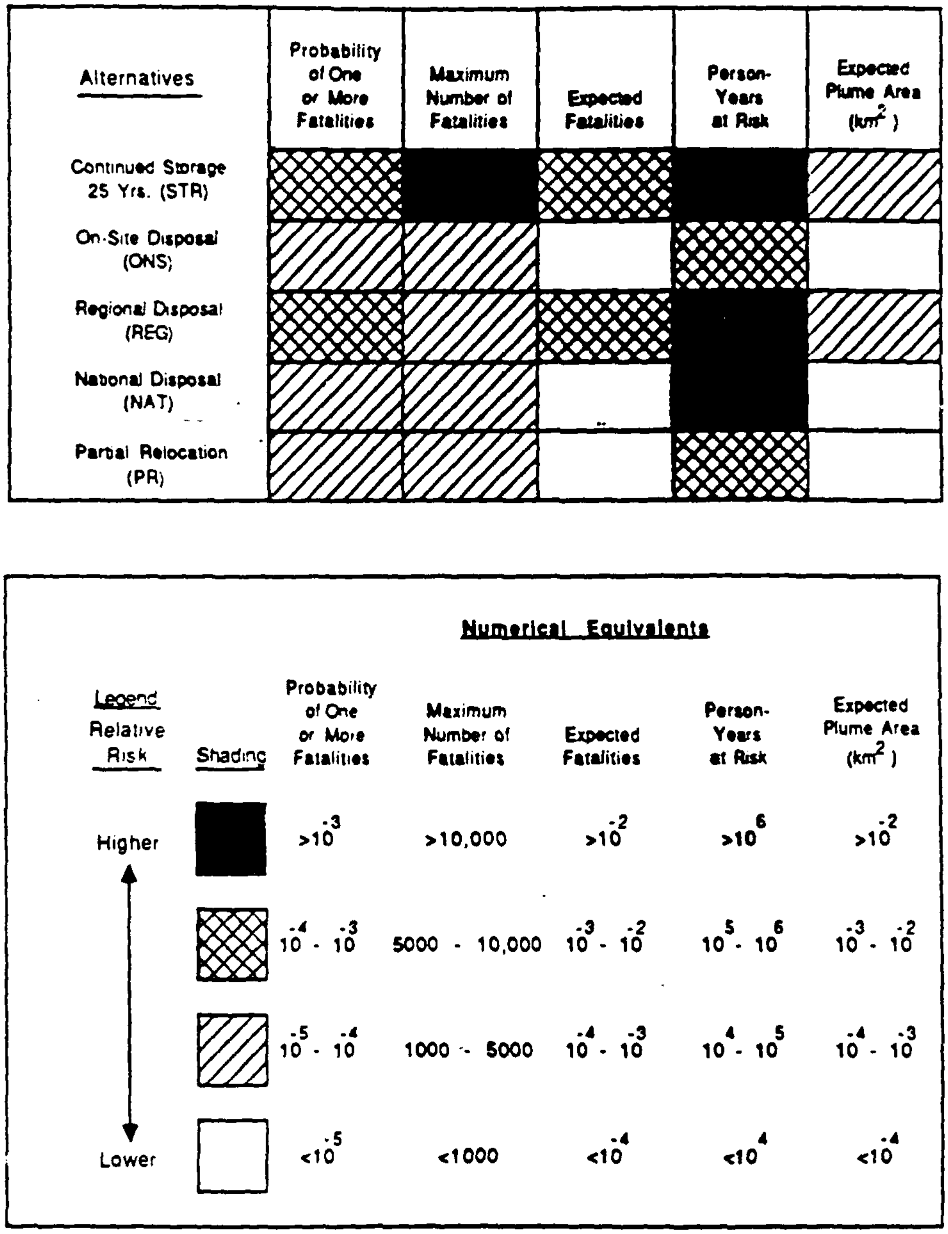


FIGURE 48

RISK, WITH MITIGATION (REV. 1), IN THE VICINITY OF ANNISTON ARMY DEPOT (ANAD) FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridors not included)

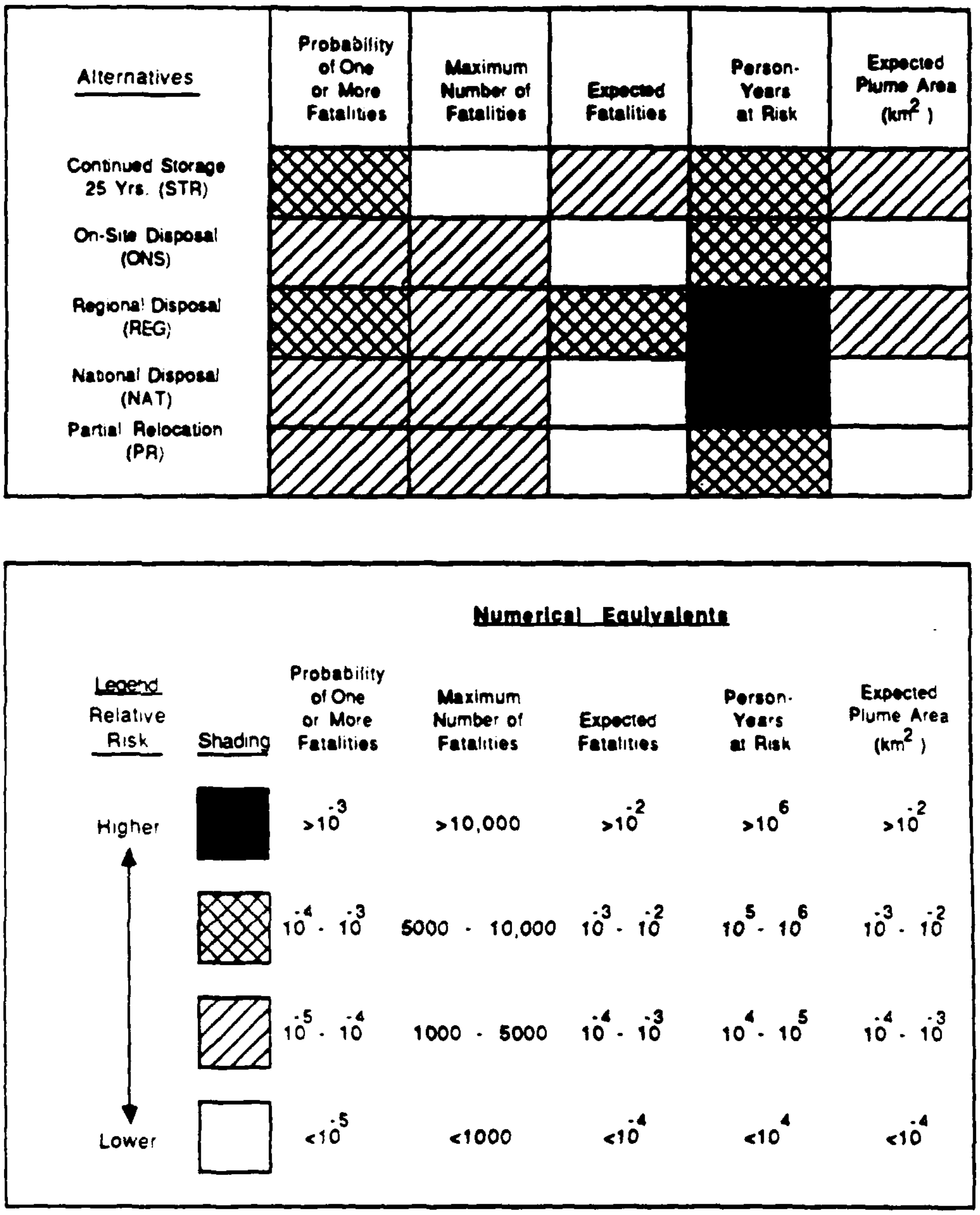
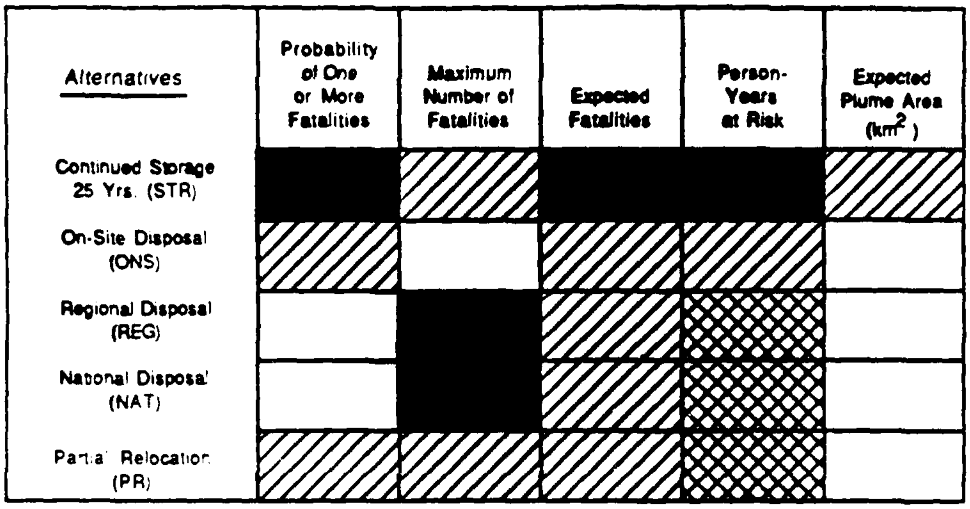


FIGURE 49

RISK, WITH MITIGATION (REV. 2), IN THE VICINITY OF ANNISTON ARMY DEPOT (ANAD) FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridors not included)



Numerical Equivalents

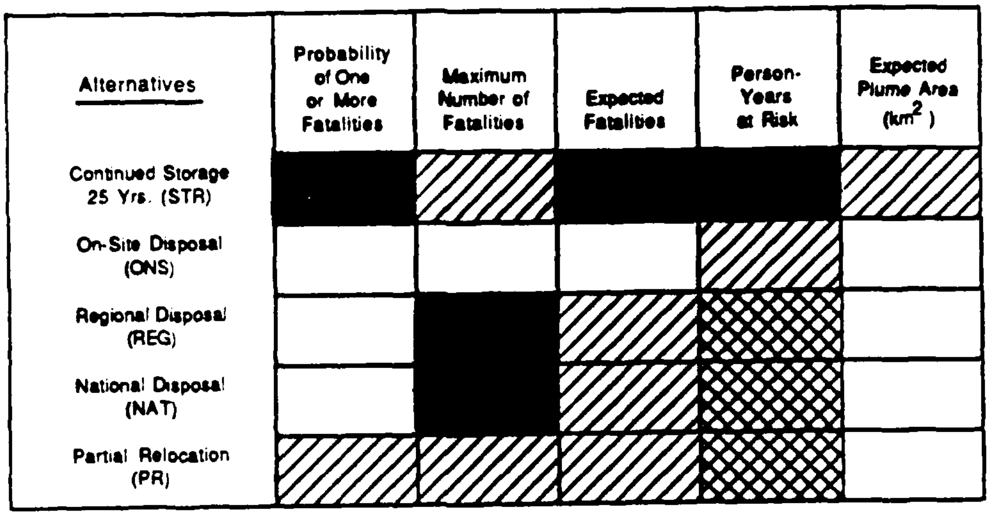
Legend

Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km²)
Higher		$>10^{-3}$	>10,000	$>10^{-2}$	$>10^{6}$	$>10^{-2}$
		$10^{-4} - 10^{-3}$	5000 - 10,000	$10^{-3} - 10^{-2}$	$10^{5} - 10^{6}$	$10^{-3} - 10^{-2}$
		$10^{-5} - 10^{-4}$	1000 - 5000	$10^{-4} - 10^{-3}$	$10^{4} - 10^{5}$	$10^{-4} - 10^{-3}$
Lower		$<10^{-5}$	<1000	$<10^{-4}$	$<10^{4}$	$<10^{-4}$

FIGURE 50

RISK IN THE VICINITY OF ABERDEEN PROVING GROUND (APG) FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridors or not included)



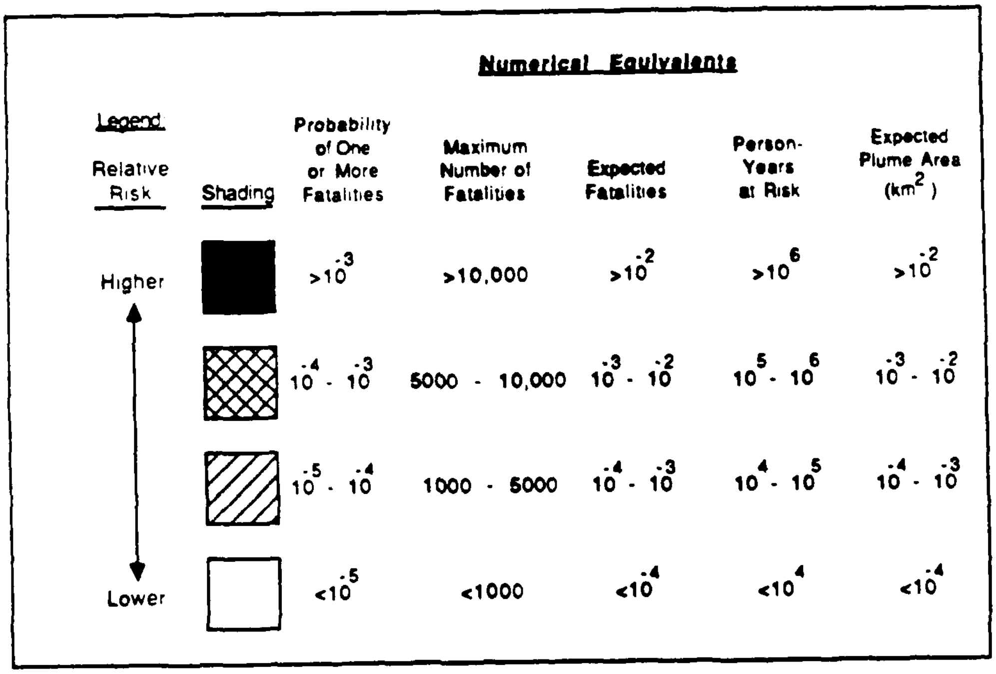


FIGURE 51

RISK, WITH MITIGATION (REV. 1), IN THE VICINITY OF ABERDEEN PROVING GROUND (APG) FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridors not included)

Alternatives	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Continued Storage 25 Yrs. (STR)					
On-Site Disposal (ONS)					
Regional Disposal (REG)					
National Disposal (NAT)					
Partial Relocation (PR)					

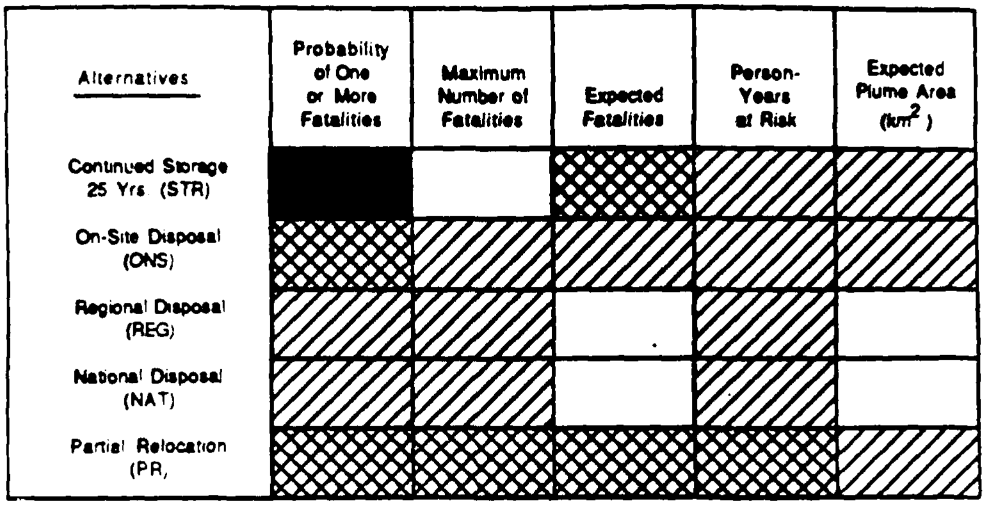
Numerical Equivalents

Legend Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-3}$	>10,000	$>10^{-2}$	$>10^{6}$	$>10^{-2}$
		$10^{-4} - 10^{-3}$	5000 - 10,000	$10^{-3} - 10^{-2}$	$10^{5} - 10^{6}$	$10^{-3} - 10^{-2}$
		$10^{-5} - 10^{-4}$	1000 - 5000	$10^{-4} - 10^{-3}$	$10^{4} - 10^{5}$	$10^{-4} - 10^{-3}$
Lower		$<10^{-5}$	<1000	$<10^{-4}$	$<10^{4}$	$<10^{-4}$

FIGURE 52

RISK, WITH MITIGATION (REV. 2), IN THE VICINITY OF ABERDEEN PROVING GROUND (APG) FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridors not included)



Numerical Equivalents

Legend Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-3}$	>10,000	$>10^{-2}$	$>10^{6}$	$>10^{-2}$
		$10^{-4} - 10^{-3}$	5000 - 10,000	$10^{-3} - 10^{-2}$	$10^{5} - 10^{6}$	$10^{-3} - 10^{-2}$
		$10^{-5} - 10^{-4}$	1000 - 5000	$10^{-4} - 10^{-3}$	$10^{4} - 10^{5}$	$10^{-4} - 10^{-3}$
Lower		$<10^{-5}$	<1000	$<10^{-4}$	$<10^{4}$	$<10^{-4}$

FIGURE 53

RISK IN THE VICINITY OF LEXINGTON-BLUE GRASS ARMY DEPOT (LBAD) FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridors not included)

Alternatives	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Continued Storage 25 Yrs. (STR)					
On-Site Disposal (ONS)					
Regional Disposal (REG)					
National Disposal (NAT)					
Partial Relocation (PR)					

Numerical Equivalents

Legend

Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-3}$	>10,000	$>10^{-2}$	$>10^{6}$	$>10^{-2}$
		$10^{-4} - 10^{-3}$	5000 - 10,000	$10^{-3} - 10^{-2}$	$10^{5} - 10^{6}$	$10^{-3} - 10^{-2}$
		$10^{-5} - 10^{-4}$	1000 - 5000	$10^{-4} - 10^{-3}$	$10^{4} - 10^{5}$	$10^{-4} - 10^{-3}$
Lower		$<10^{-5}$	<1000	$<10^{-4}$	$<10^{4}$	$<10^{-4}$

FIGURE 54

RISK, WITH MITIGATION (REV. 1), IN THE VICINITY OF LEXINGTON-BLUE GRASS ARMY DEPOT (LBAD) FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridors not included)

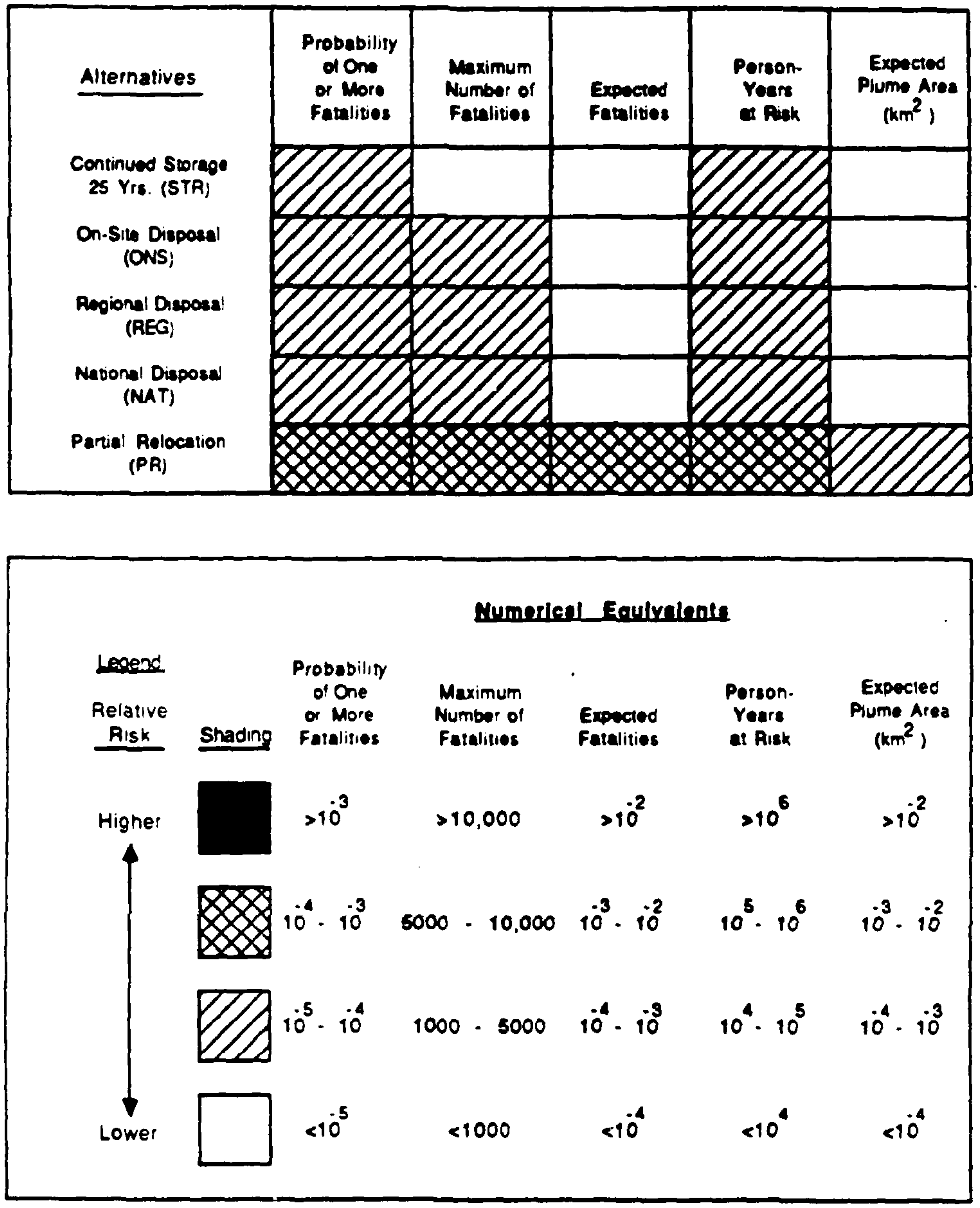


FIGURE 55

RISK, WITH MITIGATION (REV. 2),
IN THE VICINITY OF
LEXINGTON-BLUE GRASS ARMY DEPOT (LBAD)
FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridors not included)

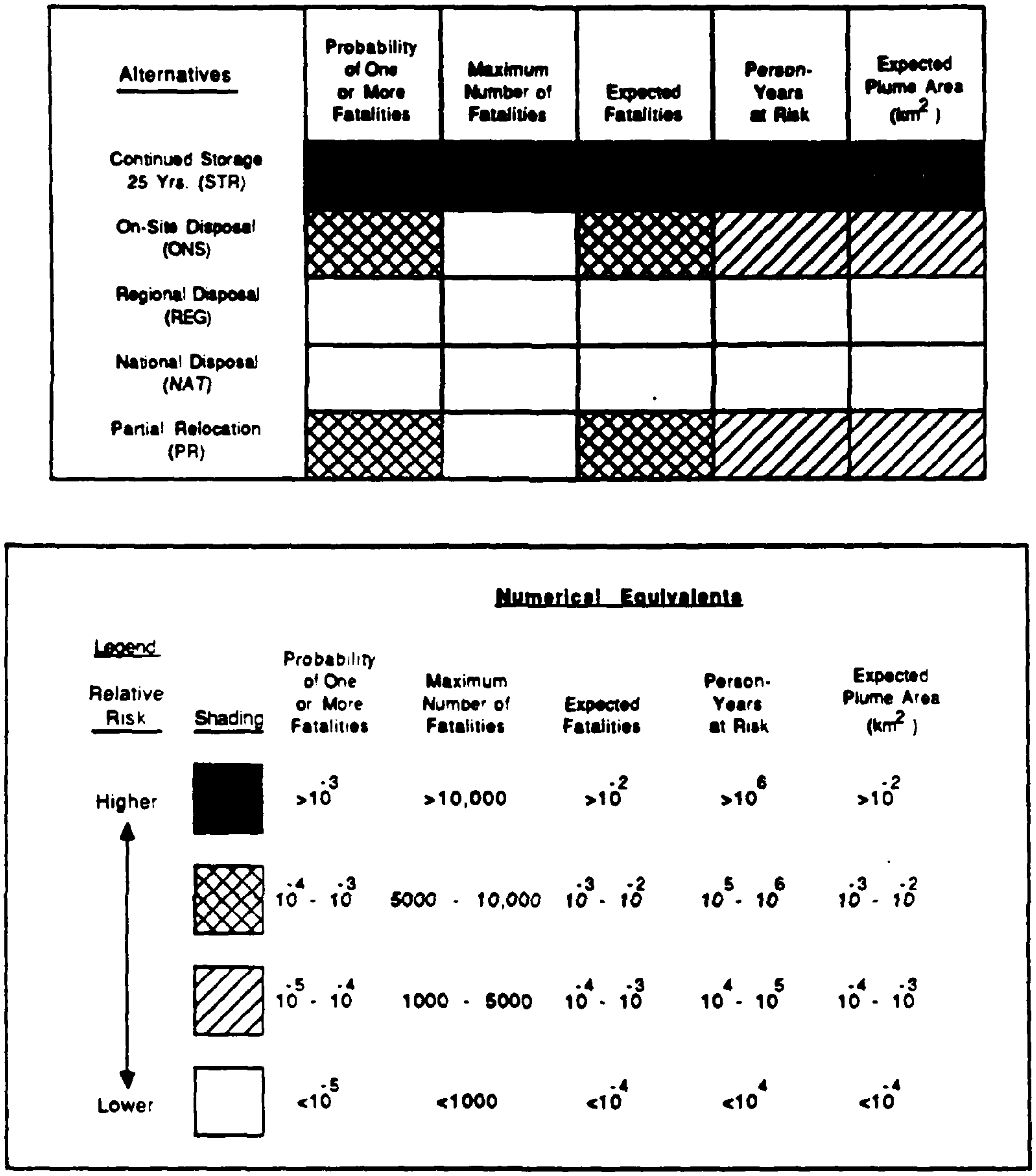


FIGURE 56

RISK IN THE VICINITY OF NEWPORT ARMY AMMUNITION PLANT (NAAP) FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridor not included)

Alternatives	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Continued Storage 25 Yrs. (STR)					
On-Site Disposal (ONS)					
Regional Disposal (REG)					
National Disposal (NAT)					
Partial Relocation (PR)					

Numerical Equivalents

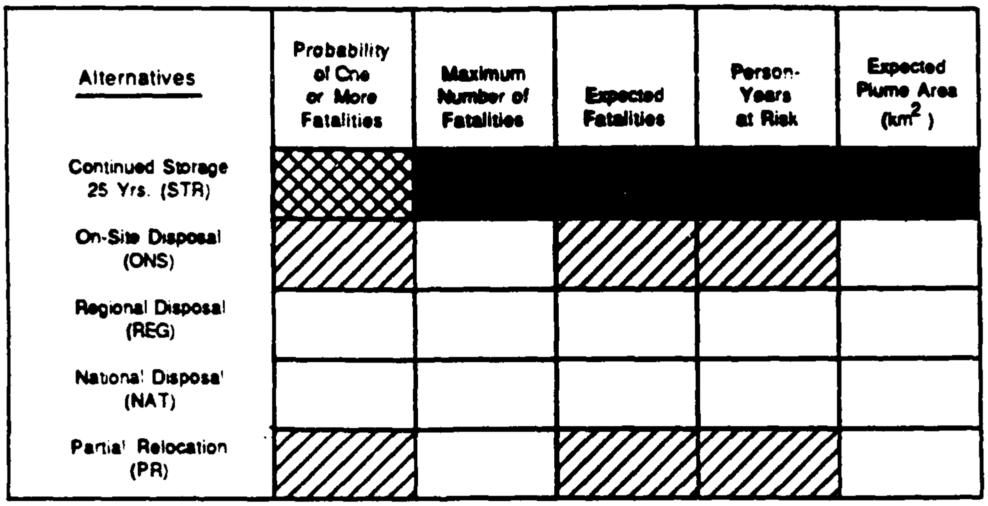
Legend

Relative Risk	Shading	Probability or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-3}$	>10,000	$>10^{-2}$	$>10^{6}$	$>10^{-2}$
		$10^{-4} - 10^{-3}$	5000 - 10,000	$10^{-3} - 10^{-2}$	$10^{5} - 10^{6}$	$10^{-3} - 10^{-2}$
		$10^{-5} - 10^{-4}$	1000 - 5000	$10^{-4} - 10^{-3}$	$10^{4} - 10^{5}$	$10^{-4} - 10^{-3}$
Lower		$<10^{-5}$	<1000	$<10^{-4}$	$<10^{4}$	$<10^{-4}$

FIGURE 57

RISK, WITH MITIGATION (REV. 1), IN THE VICINITY OF NEWPORT ARMY AMMUNITION PLANT (NAAP) FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridors not included)



Numerical Equivalents

Legend Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-3}$	>10,000	$>10^{-2}$	$>10^{6}$	$>10^{-2}$
		$10^{-4} - 10^{-3}$	5000 - 10,000	$10^{-3} - 10^{-2}$	$10^{5} - 10^{6}$	$10^{-3} - 10^{-2}$
		$10^{-5} - 10^{-4}$	1000 - 5000	$10^{-4} - 10^{-3}$	$10^{4} - 10^{5}$	$10^{-4} - 10^{-3}$
Lower		$<10^{-5}$	<1000	$<10^{-4}$	$<10^{4}$	$<10^{-4}$

FIGURE 58

RISK, WITH MITIGATION (REV. 2), IN THE VICINITY OF NEWPORT ARMY AMMUNITION PLANT (NAAP) FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridors not included)

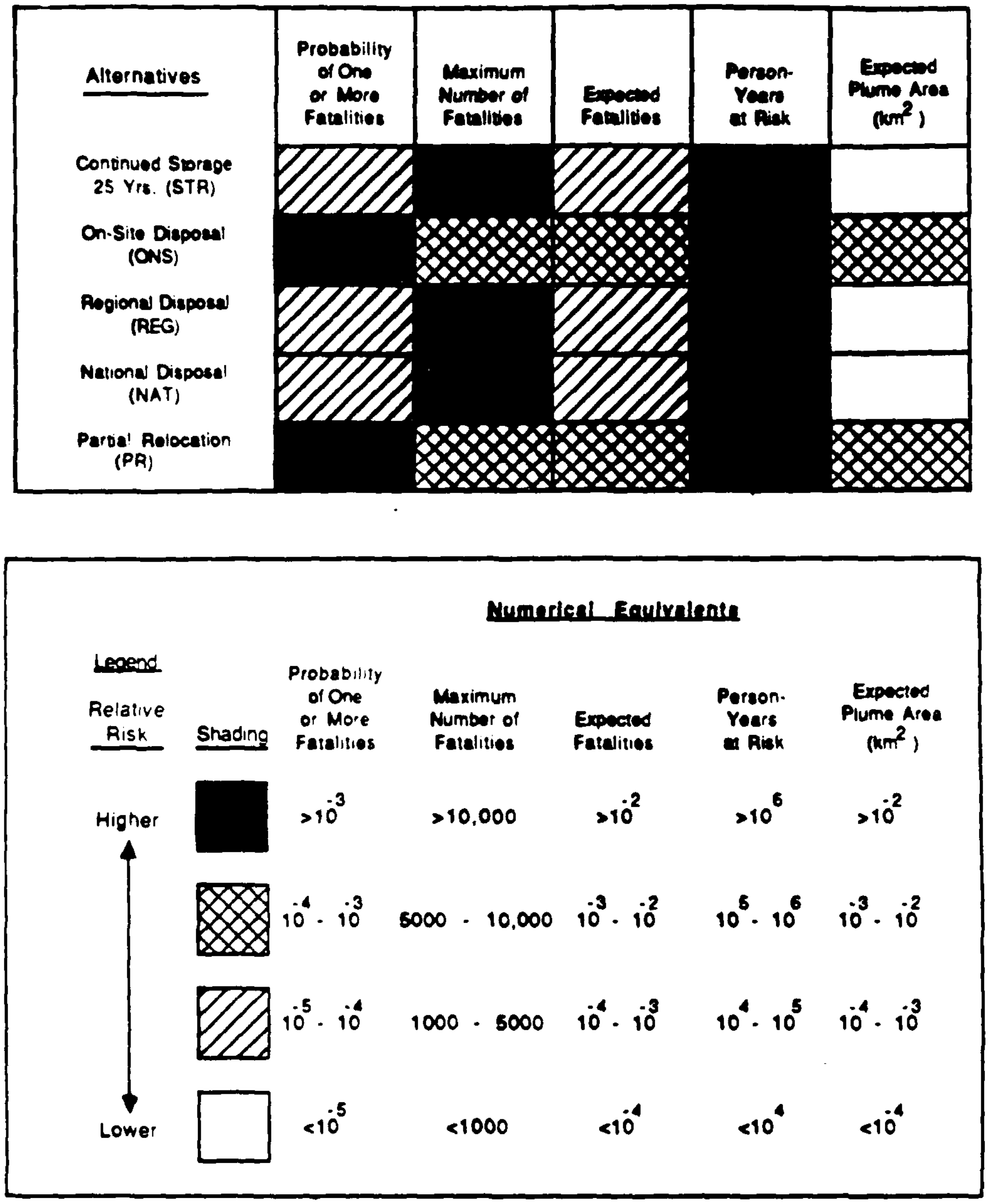
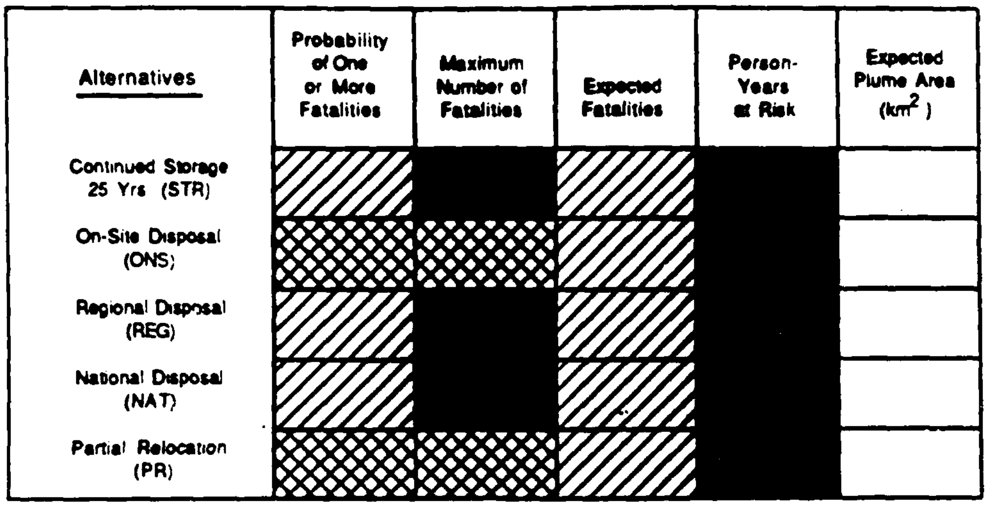


FIGURE 59

RISK IN THE VICINITY OF PINE BLUFF ARSENAL (PBA) FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridors or not included)



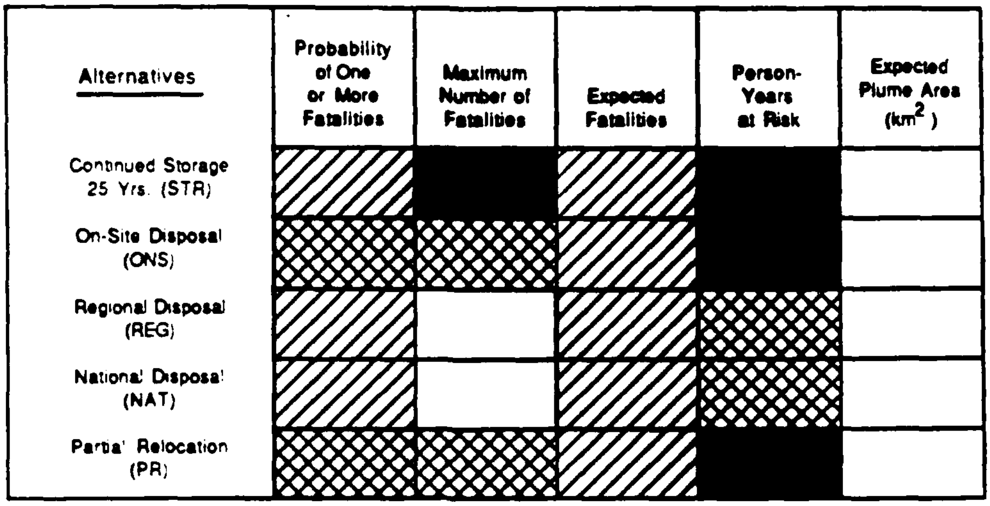
Numerical Equivalents

Legend: Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-3}$	>10,000	$>10^{-2}$	$>10^{6}$	$>10^{-2}$
		$10^{-4} - 10^{-3}$	5000 - 10,000	$10^{-3} - 10^{-2}$	$10^{5} - 10^{6}$	$10^{-3} - 10^{-2}$
		$10^{-5} - 10^{-4}$	1000 - 5000	$10^{-4} - 10^{-3}$	$10^{4} - 10^{5}$	$10^{-4} - 10^{-3}$
Lower		$<10^{-5}$	<1000	$<10^{-4}$	$<10^{4}$	$<10^{-4}$

FIGURE 60

RISK, WITH MITIGATION (REV. 1), IN THE VICINITY OF PINE BLUFF ARSENAL (PBA) FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridors not included)



Numerical Equivalents

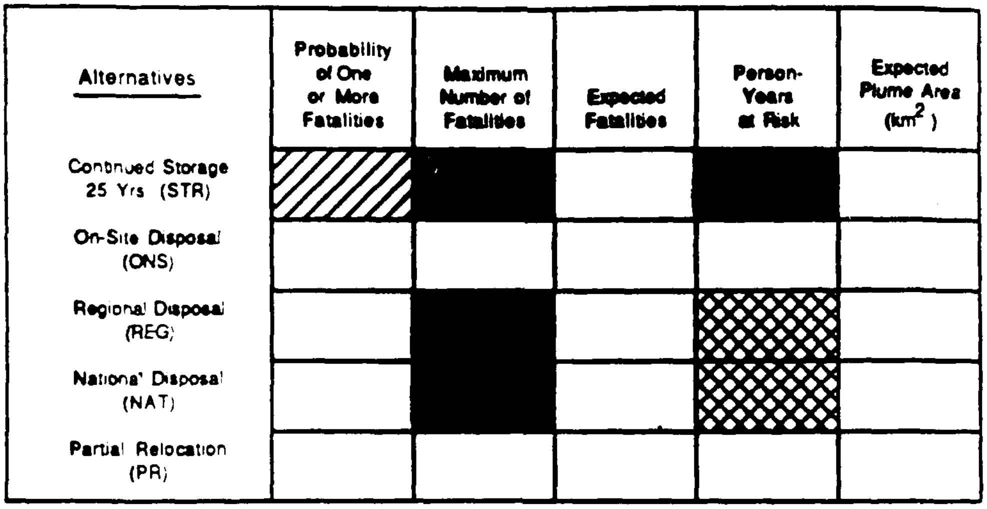
Legend

Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-3}$	>10,000	$>10^{-2}$	$>10^{6}$	$>10^{-2}$
		$10^{-4} - 10^{-3}$	5000 - 10,000	$10^{-3} - 10^{-2}$	$10^{5} - 10^{6}$	$10^{-3} - 10^{-2}$
		$10^{-5} - 10^{-4}$	1000 - 5000	$10^{-4} - 10^{-3}$	$10^{4} - 10^{5}$	$10^{-4} - 10^{-3}$
Lower		$<10^{-5}$	<1000	$<10^{-4}$	$<10^{4}$	$<10^{-4}$

FIGURE 61

RISK, WITH MITIGATION (REV. 2), IN THE VICINITY OF PINE BLUFF ARSENAL (PBA) FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridors not included)



Numerical Equivalents

Legend

Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-3}$	>10,000	$>10^{-2}$	$>10^{6}$	$>10^{-2}$
		$10^{-4} - 10^{-3}$	5000 - 10,000	$10^{-3} - 10^{-2}$	$10^{5} - 10^{6}$	$10^{-3} - 10^{-2}$
		$10^{-5} - 10^{-4}$	1000 - 5000	$10^{-4} - 10^{-3}$	$10^{4} - 10^{5}$	$10^{-4} - 10^{-3}$
Lower		$<10^{-5}$	<1000	$<10^{-4}$	$<10^{4}$	$<10^{-4}$

FIGURE 62

RISK IN THE VICINITY OF PUEBLO DEPOT ACTIVITY (PUDA) FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridors not included)

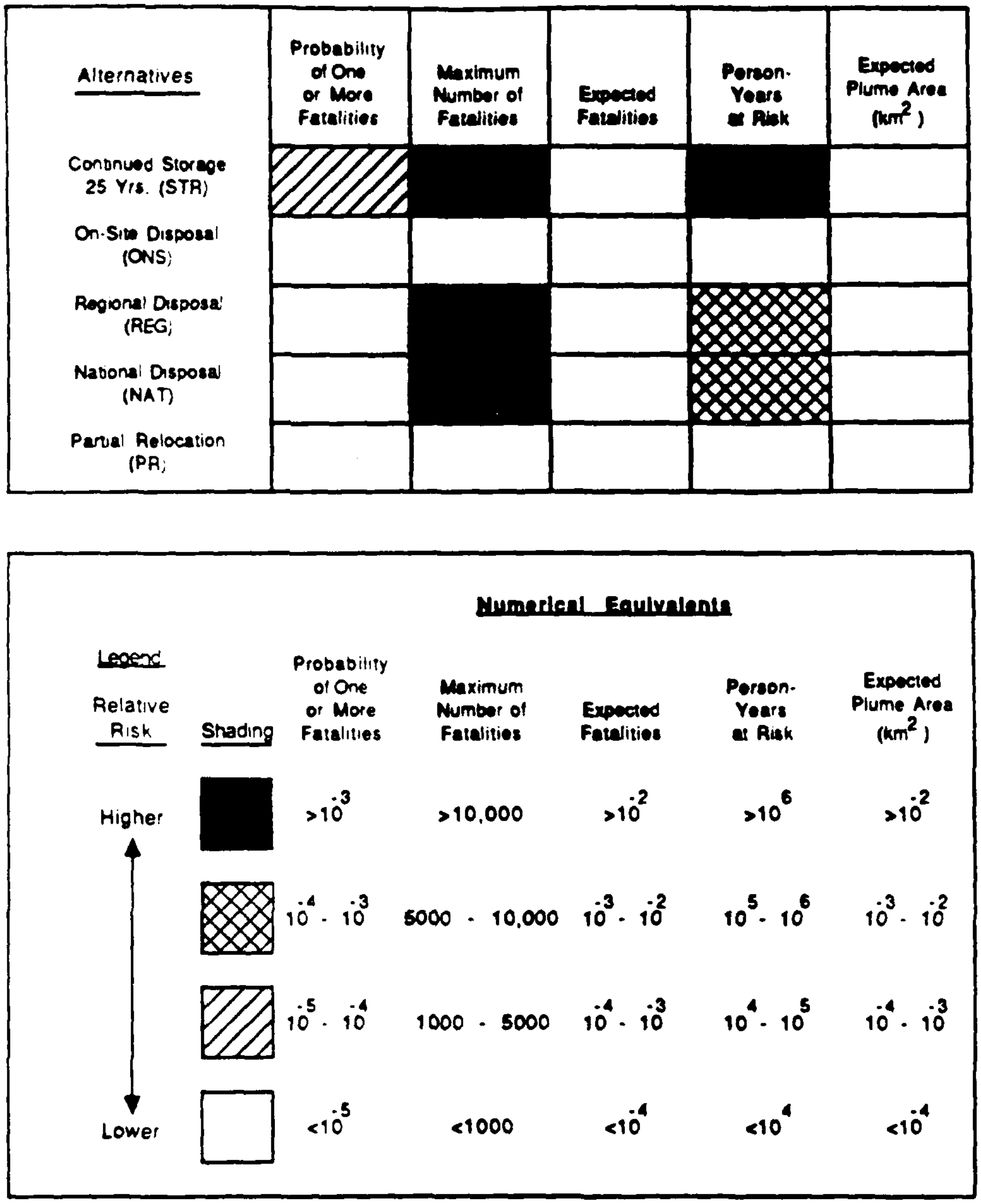


FIGURE 63

RISK, WITH MITIGATION (REV. 1), IN THE VICINITY OF PUEBLO DEPOT ACTIVITY (PUDA) FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridors not included)

Alternatives	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Continued Storage 25 Yrs. (STR)					
On-Site Disposal (ONS)					
Regional Disposal (REG)					
National Disposal (NAT)					
Partial Relocation (PR)					

Numerical Equivalents

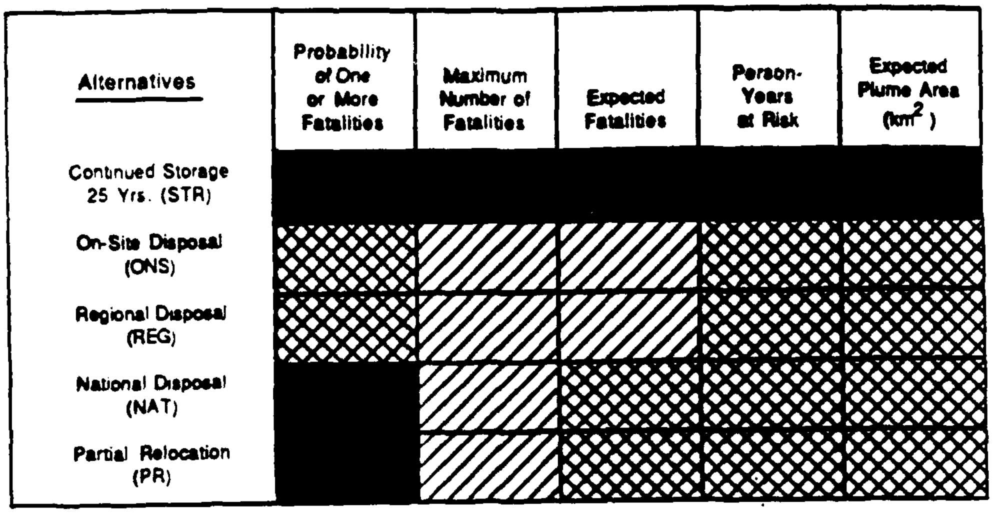
Legend

Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-3}$	>10,000	$>10^{-2}$	$>10^{6}$	$>10^{-2}$
		$10^{-4} - 10^{-3}$	5000 - 10,000	$10^{-3} - 10^{-2}$	$10^{5} - 10^{6}$	$10^{-3} - 10^{-2}$
		$10^{-5} - 10^{-4}$	1000 - 5000	$10^{-4} - 10^{-3}$	$10^{4} - 10^{5}$	$10^{-4} - 10^{-3}$
Lower		$<10^{-5}$	<1000	$<10^{-4}$	$<10^{4}$	$<10^{-4}$

FIGURE 64

RISK, WITH MITIGATION (REV. 2), IN THE VICINITY OF PUEBLO DEPOT ACTIVITY (PUDA) FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridors not included)



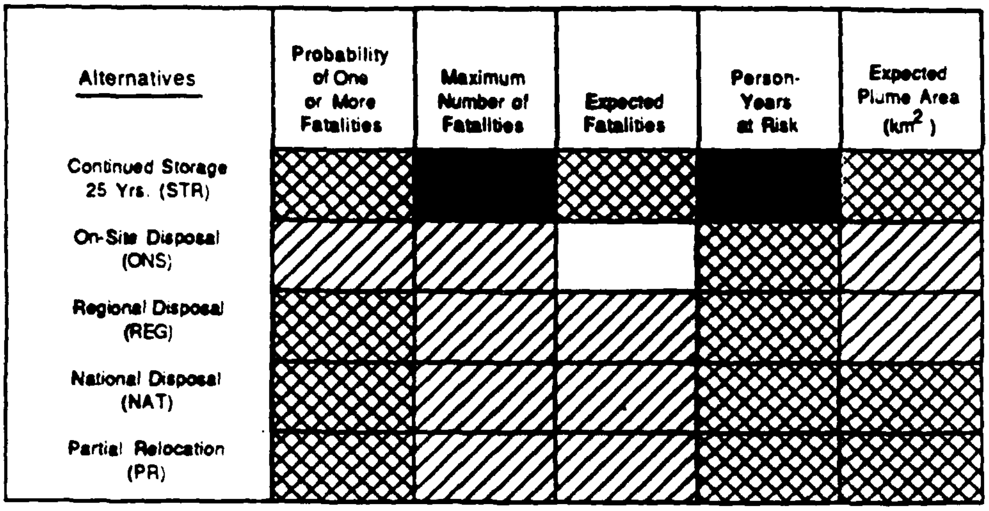
Numerical Equivalents

Legend Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-3}$	>10,000	$>10^{-2}$	$>10^{6}$	$>10^{-2}$
		10^{-4} - 10^{-3}	5000 - 10,000	10^{-3} - 10^{-2}	10^{5} - 10^{6}	10^{-3} - 10^{-2}
		10^{-5} - 10^{-4}	1000 - 5000	10^{-4} - 10^{-3}	10^{4} - 10^{5}	10^{-4} - 10^{-3}
Lower		$<10^{-5}$	<1000	$<10^{-4}$	$<10^{4}$	$<10^{-4}$

FIGURE 65

RISK IN THE VICINITY OF TOOELE ARMY DEPOT (TEAD) FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridors not included)



Numerical Equivalents

Legend

Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-3}$	>10,000	$>10^{-2}$	$>10^{6}$	$>10^{-2}$
		10^{-4} - 10^{-3}	5000 - 10,000	10^{-3} - 10^{-2}	10^{5} - 10^{6}	10^{-3} - 10^{-2}
		10^{-5} - 10^{-4}	1000 - 5000	10^{-4} - 10^{-3}	10^{4} - 10^{5}	10^{-4} - 10^{-3}
Lower		$<10^{-5}$	<1000	$<10^{-4}$	$<10^{4}$	$<10^{-4}$

FIGURE 66

RISK, WITH MITIGATION (REV.1), IN THE VICINITY OF TOOELE ARMY DEPOT (TEAD) FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridors not included)

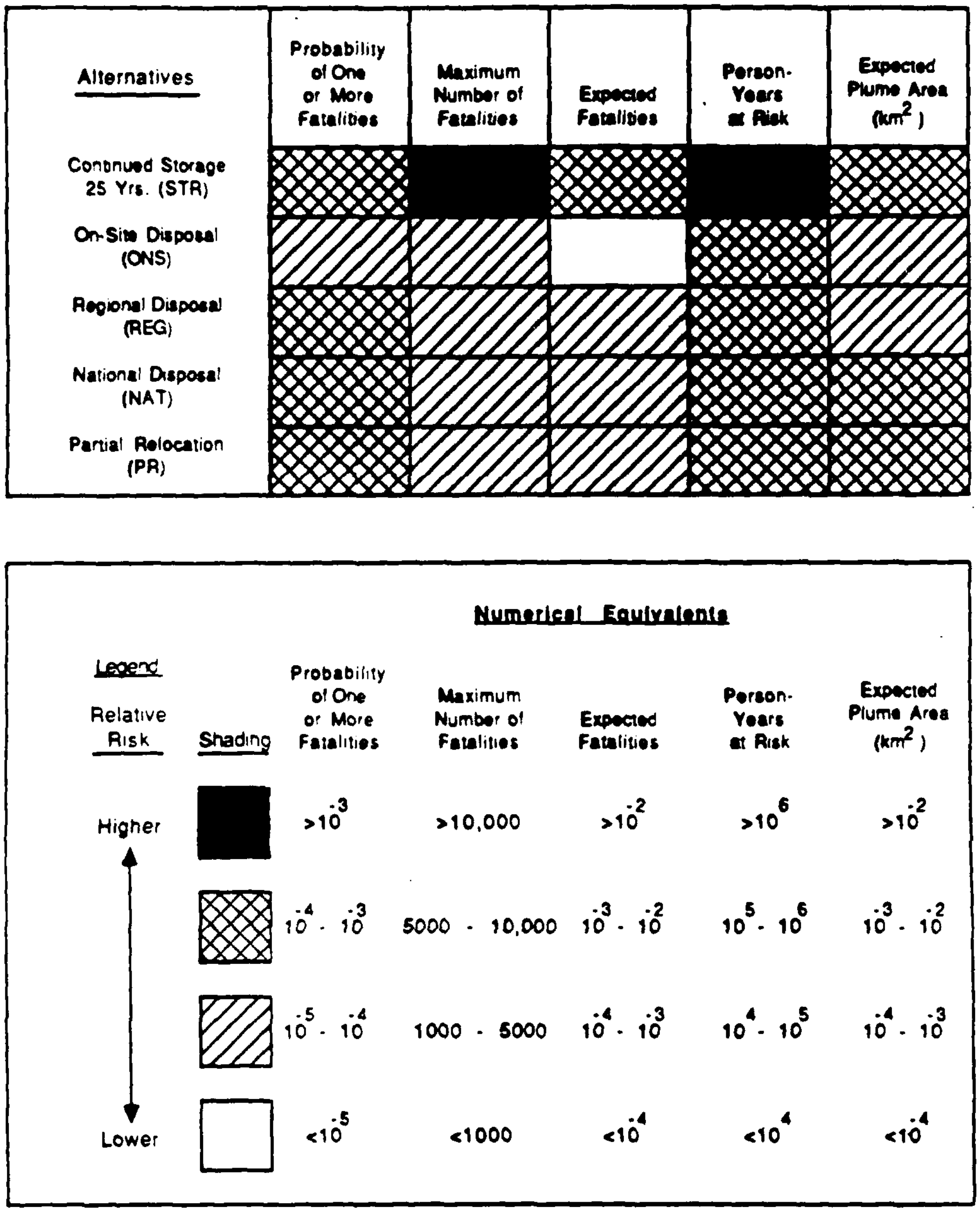


FIGURE 67

RISK, WITH MITIGATION (REV.2), IN THE VICINITY OF TOOELE ARMY DEPOT (TEAD) FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridors not included)

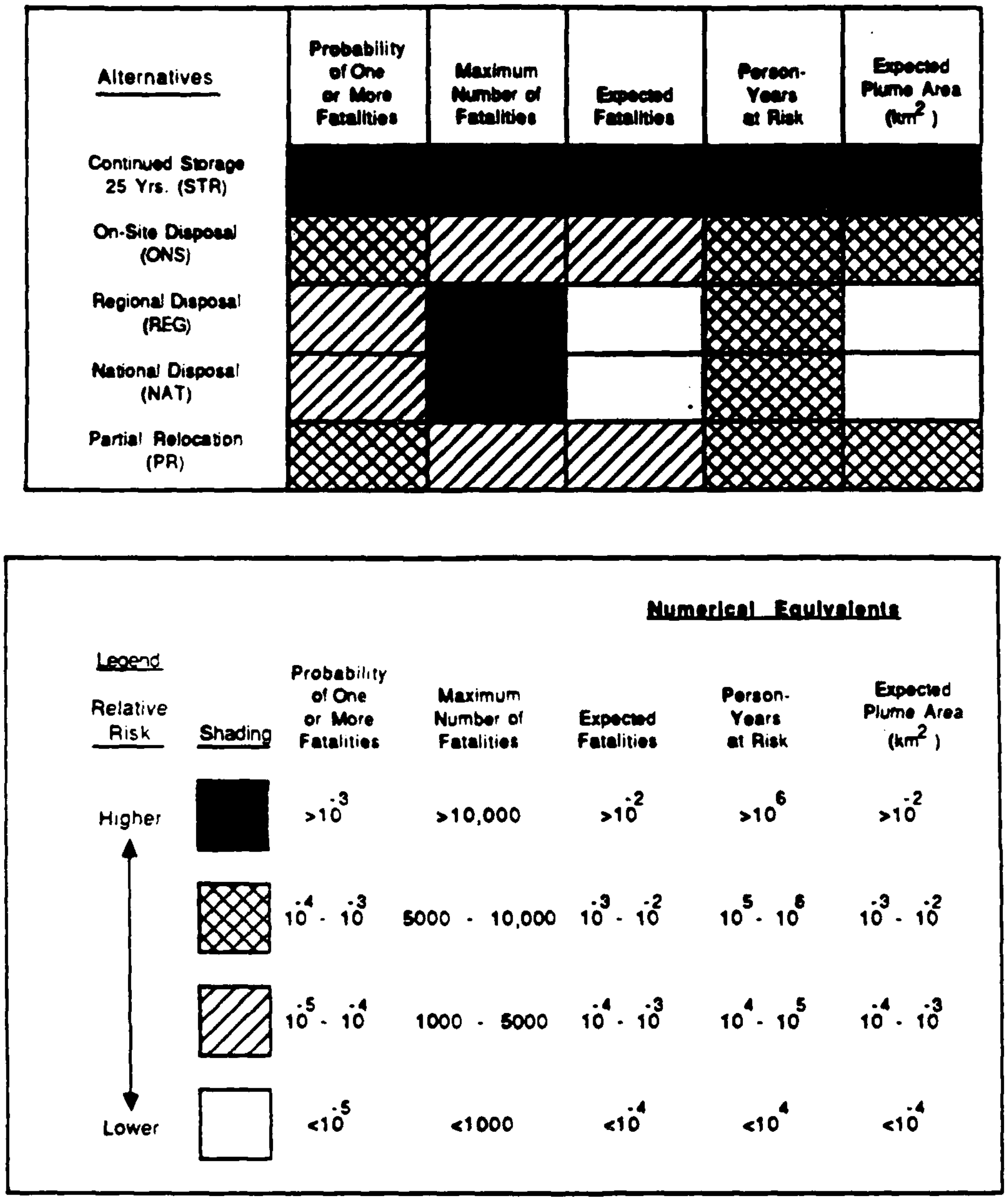
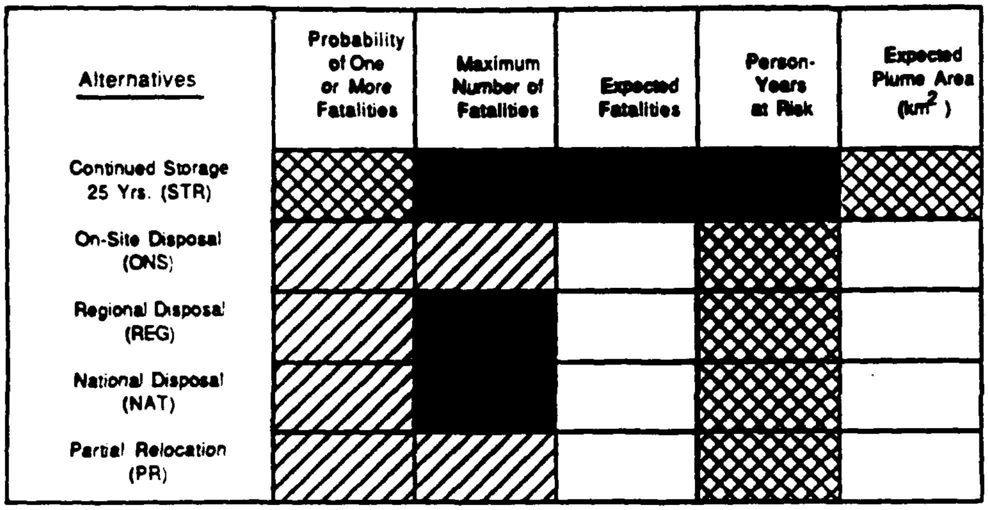


FIGURE 68

RISK IN THE VICINITY OF UMATILLA DEPOT ACTIVITY (UMDA) FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridors not included)



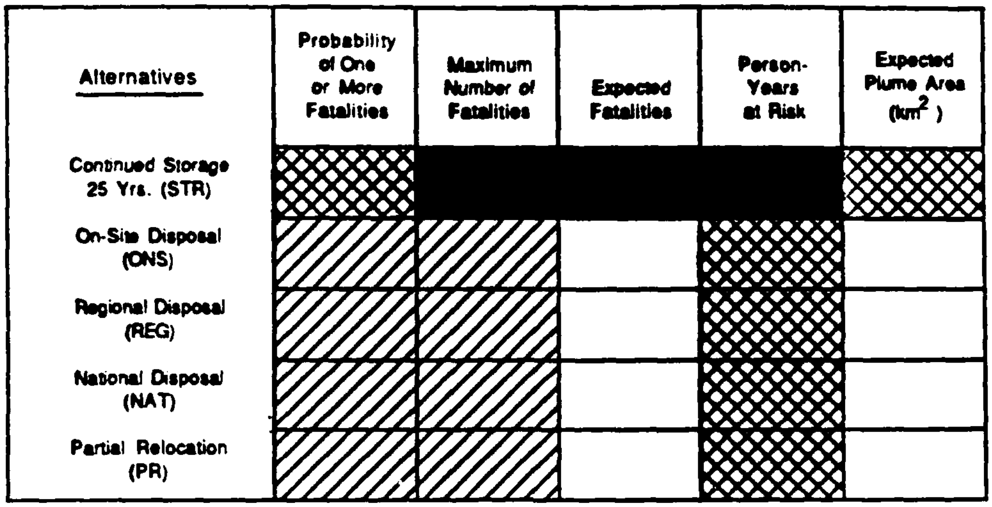
Numerical Equivalents

Legend Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-3}$	>10,000	$>10^{-2}$	$>10^{6}$	$>10^{-2}$
		10^{-4} - 10^{-3}	5000 - 10,000	10^{-3} - 10^{-2}	10^{5} - 10^{6}	10^{-3} - 10^{-2}
		10^{-5} - 10^{-4}	1000 - 5000	10^{-4} - 10^{-3}	10^{4} - 10^{5}	10^{-4} - 10^{-3}
Lower		$<10^{-5}$	<1000	$<10^{-4}$	$<10^{4}$	$<10^{-4}$

FIGURE 69

RISK, WITH MITIGATION (REV. 1), IN THE VICINITY OF UMATILLA DEPOT ACTIVITY (UMDA) FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridors not included)



Numerical Equivalents

Legend:

Relative Risk	Shading	Probability of One or More Fatalities	Maximum Number of Fatalities	Expected Fatalities	Person-Years at Risk	Expected Plume Area (km^2)
Higher		$>10^{-3}$	>10,000	$>10^{-2}$	$>10^{6}$	$>10^{-2}$
		10^{-4} - 10^{-3}	5000 - 10,000	10^{-3} - 10^{-2}	10^{5} - 10^{6}	10^{-3} - 10^{-2}
		10^{-5} - 10^{-4}	1000 - 5000	10^{-4} - 10^{-3}	10^{4} - 10^{5}	10^{-4} - 10^{-3}
Lower		$<10^{-5}$	<1000	$<10^{-4}$	$<10^{4}$	$<10^{-4}$

FIGURE 70

RISK, WITH MITIGATION (REV. 2), IN THE VICINITY OF UMATILLA DEPOT ACTIVITY (UMDA) FOR PROGRAMMATIC ALTERNATIVES

(Risk along transportation corridors not included)

total programmatic risk dropping from over 10 percent (mitigation, revision 1) to well less than 1 percent.

- Risk is somewhat more evenly shared for the unmitigated <u>on-site</u> disposal alternative, but even here, large disparities exist: 48 percent of the total risk would be experienced at PBA, with 2 percent or less of the total borne at each of four sites -- APG, LBAD, PUDA and UMDA. When mitigation is introduced, overall risk drops by more than a factor of 10, and 75 percent of the reduced programmatic risk is borne in approximately equal shares by PBA and NAAP; LBAD, ANAD, and TEAD each experience between 5 percent and 10 percent of the total, with the remaining sites bearing less than 3 percent each of the total (reduced) programmatic risk. Air-space restriction has no effect on this alternative.

- For the <u>regional</u> alternative, 63 percent of the total programmatic risk is borne by the population groups along the transportation corridors, and only 3 percent is felt by the populations near the originating sites; the remaining 34 percent is borne by the destination site populations (ANAD and TEAD), with ANAD's share three times TEAD's. Risk along the transportation corridors is due principally to shipment of the PBA and LBAD stockpiles. When mitigation is introduced, the risk borne by the corridor populations rises to over 75 percent of the slightly lower (by 20 percent) total risk; the disposal sites (ANAD and TEAD) now experience less than 20 percent of the total -- most of that risk carried by the ANAD area; transportation corridor risk remains essentially unchanged in an absolute sense. Air-space restrictions would reduce the originating site contribution to total risk, with the major benefit seen at APG (where risk is reduced to less than 10^{-6}.

- 92 percent of the risk for the <u>national</u> alternative is distributed along the transportation corridors, leaving less than 2 percent of the risk to be borne by the originating sites. The remaining 6 percent of the total is felt by the TEAD population group. Of the transportation corridor risk, over 50 percent is the result of transporting the ANAD stockpile; the LBAD and PBA stockpiles also contribute nearly 20 percent each. With mitigation (revision 1), disposal site (TEAD) total risk drops from 6 percent to 1 percent of the total with transportation corridor population groups seeing their share of the risk rise to 98 percent of the total; originating site risk is hardly affected. Air-space restriction benefits principally the (originating-site) risk at APG, and reduces the already small originating-site contribution (all sites) to total programmatic risk to under 1 percent.

- For the partial relocation alternative, nearly half the risk is borne by the corridor populations, with the air-movement of the LBAD stockpile contributing over 98 percent of the corridor risk (68 percent of total risk for the alternative). TEAD sees only 3 percent of the risk, while LBAD and APG as the originating sites contribute roughly 25 percent and 5 percent, respectively; risk at the remaining sites is the same as for the on-site alternative. Mitigation, which reduces the programmatic risk for this alternative by over 25 percent, leads to a situation where 62 percent of the risk is experienced by corridor populations and less than 2 percent is seen by TEAD; the originating site risk at LBAD is not affected by these mitigation measures, so it's contribution to the total grows to over 30 percent. The effects of air-space restrictions on risk and its distribution for this alternative are negligible.

3.3.2 Factors Contributing to Community/Societal Risk, by Location

Risk at disposal/storage sites includes all activities that take place there. These include both storage and disposal activities, as well as any activities (such as extra handling and temporary storage while awaiting shipment) that could be associated with preparing the stockpile for off-site transport. The sites are identified by the codes listed in section 3.1.1.

3.3.2.1 Anniston Army Depot (ANAD). Figures 47 through 49 display the major risk measures for all applicable disposal alternatives at ANAD; each figure portrays either the unmitigated case or one of the two levels of mitigation. Considering first the unmitigated case, Figure 47 shows that for all major risk measures, continued storage poses the highest risk of any alternative. Among the disposal alternatives, all appear to pose the same risk (within the numerical ranges defining the 'pictogram' shadings) to the public except for national disposal for which risk is one or two categories lower for probability of one or more fatalities and expected fatalities. Person-years-at risk is high for the national and regional alternatives.

For the case of no mitigation, the major contributors to community/societal risk to the community in the vicinity of ANAD, as measured by expected fatalities, for each of the disposal alternatives is summarized below:

- Continued storage risk at ANAD is mostly (90 percent) due to handling activities; the remainder of the risk results from external events affecting the stockpile. Furthermore, over 90 percent of the risk is due to projectiles.

- For the on-site and partial relocation (which, for ANAD, is the same as on-site) alternatives, 97 percent of the risk is due to plant operations, and of that risk, roughly 70 percent is due to the disposal of mines with most of the remainder due to rockets.

- The regional disposal risk is due primarily (75 percent) to plant operations; most of the remainder (22 percent) results from on-site transport. Roughly 40 percent of total risk is due to rockets; another 40 percent is due to mines; only 1 percent of the risk results from disposal of bulk agent. The reason for the relatively high risk of the regional alternative is the need to process the additional inventory of munitions shipped in by rail from other sites.

- For the national alternative, 62 percent of the risk is due to on-site transport accidents and 37 percent results from handling accidents. Among the munition types, nearly 80 percent of the risk results from rockets, with the remainder split evenly between mines and projectiles.

The introduction of mitigation, revision 1 (all measures except air-space restriction) results in some risk reduction at ANAD (see Figure 48). Significant reductions may be realized for continued storage and the on-site disposal alternative; less benefit can be expected for the regional and partial relocation alternatives. The major impacts of mitigation for each alternative are summarized below:

- For continued storage, mitigation reduces the probability of one or more fatalities and expected fatalities by an order of magnitude. Since the highest consequence accident (an aircraft crash) is not mitigated, there is no reduction in maximum number of fatalities or person-years-at-risk. With mitigation, nearly 90 percent of the expected fatalities are due to external events, although handling accidents remain the major contributor to probability of one or more fatalities. Mitigation reduces the risk due to projectiles by a factor of more than 10, without affecting the risk due to rockets; as a result, with mitigation, projectiles would contribute less than 60 percent to risk, with the remainder due to rockets.

- For on-site disposal (same as partial relocation at ANAD), mitigation reduces the probability of one or more fatalities and expected fatalities by about 95 percent. Since the highest consequence accident (detonation during on-site transport) is not mitigated significantly, there is no reduction in the maximum number of fatalities or person-years-at-risk measures. With mitigation, the greatest risk contributor is the accident involving detonation during on-site transport, representing 40 percent of the

total; plant operations accidents account for nearly 40 percent of the total as well.

- For regional disposal, mitigation reduces **probability of one or more fatalities** by about 80 percent and **expected fatalities** by 50 percent; the other risk measures remain unchanged. Most of the risk (approximately 95 percent) is attributable to an on-site accident involving a detonation. Mines are responsible for about 60 percent of the risk; rockets contribute 10 percent.

- Mitigation has no significant effect on any of the risk measures for the national alternative.

With the addition of air-space restriction (see Figure 49) to the mitigation measures discussed above, only the continued storage is affected. Relative to mitigation without air-space restriction (revision 1), **expected fatalities** would be reduced by nearly 90 percent and **maximum number of fatalities** and **person-years-at-risk** would be more than 99 percent lower. However, the **probability of one or more fatalities** is not reduced significantly by the restriction of air-space -- the reason being that this measure is dominated by other, higher probability events which are not mitigated by air-space restriction.

3.3.2.2 Aberdeen Proving Ground (APG). The risk from the various disposal alternatives to the population about APG is illustrated by the 'pictograms' in Figures 50 through 52, covering the unmitigated case plus two levels of mitigation. For the unmitigated case (Figure 50), it appears that, except for the **probability of one or more fatalities**, all risk measures indicate that the on-site alternative poses the least risk. On the basis of **expected fatalities**, the risk due to the disposal alternatives is roughly the same (within 25 percent) for all. Risk associated with the continued storage alternative is greater than for any of the disposal alternatives by a factor of 10 - 100.

The major contributors to risk for each unmitigated alternative at APG are summarized below:

- 100 percent of the continued storage risk is due to external events (aircraft crashes) during storage; there are no handling events of risk significance, a result of the fact that APG's stockpile consists only of mustard agent in bulk containers, and the handling accidents lead only to spills or spills with fire which do not create plumes that move beyond the boundary of the military reservation.

- For the on-site alternative, 100 percent of the risk results from plant operations.

- The risk due to regional and national alternatives (the same for those living near APG) is due entirely to accidents during short-term storage related to off-site transportation via rail.

- For the partial relocation -- air mode alternative, more than 95 percent of the risk arises from off-site transportation-related activities -- mainly crashes of aircraft carrying bulk containers of mustard, during take-off. The remainder of the risk results from short-term storage activities.

- For the partial relocation -- water mode alternative, the risk is about evenly split between off-site transportation-related accidents -- those affecting the loaded LASH when underway in the Chesapeake Bay -- and short-term storage accidents -- an aircraft crashing into a loaded LASH while still moored in the Aberdeen area.

For the mitigated accident scenario set (all measures except air-space restriction -- see Figure 51), the following risk reductions are realized, by disposal alternative:

- For continued storage, mitigation does not significantly change any of the measures of risk.

- For on-site disposal, mitigation reduces the probability of one or more fatalities and expected fatalities by almost an order of magnitude. Since the highest-consequence accident (an earthquake) is not sufficiently mitigated to remove it from the set of credible accidents, there is no reduction in the maximum number of fatalities or in person-years-at-risk. With mitigation, the plant operations accidents remain the only contributors to risk.

- For regional and national disposal, mitigation reduces risk by about 5 percent. Accidents during short-term storage remain the only contributors to risk.

- For partial relocation, mitigation leads to a reduction in risk of less than 20 percent. Although the consequences of a crash during take-off of an aircraft loaded with mustard bulk containers are somewhat mitigated by transporting the mustard in a frozen state, this accident remains the major contributor (>95 percent) to the risk at APG.

If air-space restrictions (mitigation, revision 2 -- see Figure 52) are introduced, significant reductions in risk at APG would result for continued storage and the national and regional alternatives. Mitigation of aircraft crashes benefits the partial relocation alternative somewhat but has no effect on the risk of the on-site disposal alternative.

- For continued storage, both expected fatalities and the probability of one or more fatalities are two orders of magnitude lower with the reduction in frequency of aircraft crash accidents. Since the consequences of this accident are not mitigated, the maximum number of fatalities and person-years-at-risk are not affected.

- For the on-site disposal alternative, restricting air-space has no effect on the risk because all accidents involving aircraft damage to the MDB have probabilities below 10^{-8} and are screened out of the analysis. Although there is a relatively high potential for small aircraft crashes at APG, such crashes are not considered to have enough impact to damage the MDB. Large aircraft crashes, which could damage the MDB, are expected to be relatively infrequent at APG.

- For the partial relocation alternative, since over 95 percent of the risk is due to crashes of aircraft carrying bulk containers of mustard, reducing the frequency of other aircraft crash accidents does not significantly reduce the risk of this alternative. However, consequences of a crash into temporary storage are greater than for a crash of the aircraft containing mustard. Therefore, eliminating the former accident reduces the maximum number of fatalities and the person-years-at-risk. With restricted air-space, the probability of this accident would drop below 10^{-8}, thus eliminating it from the data base. For this reason, the maximum number of fatalities is reduced from 2300 to about 300 and the person-years-at-risk from 4×10^5 to 2.5×10^4.

3.3.2.3 Lexington Blue-Grass Army Depot (LBAD) Figures 53 through 55 contain the 'pictogram' representation of risk at LBAD. The 'pictogram' for the unmitigated case (see Figure 53) indicates that the regional and national alternatives (identical in terms of originating site activities and risk at LBAD) pose the least risk to the population surrounding LBAD. On the basis of expected fatalities, the risk due to the national/regional alternatives is less than that due to on-site disposal by a factor of 3 or 4, while the risk due to the partial relocation (air mode) alternatives dominate by one-to-two orders of magnitude.

The contributions to risk for each unmitigated disposal alternative are summarized below:

- For continued storage at LBAD, essentially all of the risk arises from handling accidents associated with the maintenance of projectiles. The highest risk accidents are due to the movement of munitions for maintenance purposes.

- The risk due to <u>on-site</u> disposal results primarily (61 percent) from plant operations, with the remainder of the risk coming from on-site transportation accidents. Among munition types, rockets contribute 96 percent of the risk.

- For the <u>regional/national</u> alternatives, 100 percent of the risk results from rockets. Among activity types, 93 percent of the risk is due to on-site transportation, with handling contributing the remainder.

- For the <u>partial relocation -- air mode</u> alternative, 99 percent of the risk is due to off-site transportation-related accidents -- aircraft crashes on take-off. 90 percent to 95 percent of the total risk results from the transport of rockets.

<u>Mitigation, Revision 1</u> would significantly reduce risk for continued storage and on-site disposal (see Figure 54). It would have no effect on the other alternatives. The major contributors to risk reduction are summarized below:

- For <u>continued storage</u>, mitigation would reduce the **probability of one or more fatalities** and **expected fatalities** by roughly 98 percent. Since the consequences of the most severe accidents (handling accidents involving fires or detonations) are not mitigated, there is no reduction in the **maximum number of fatalities** or **person-years-at-risk**. Essentially all of the risk remains attributable to handling accidents -- about 70 percent of them involving projectiles.

- For <u>on-site</u> disposal, mitigation would reduce the **probability of one or more fatalities** by nearly 90 percent and **expected fatalities** by approximately 60 percent. As with continued storage, since the consequences of the most severe accidents (plant damage by earthquakes and detonations during on-site transport) are not mitigated, there is no reduction in the **maximum number of fatalities** or the **person-years-at-risk**. With mitigation, over 90 percent of the resulting risk is due to accidents involving detonation during on-site transportation. Rockets are responsible for essentially all (~99 percent) of the risk.

The introduction of <u>air-space restrictions</u> would have no risk reduction benefit for LBAD (see Figure 55), mainly because the LBAD stockpile is stored in igloos.

3.3.2.4 <u>Newport Army Ammunition Plant (NAAP)</u>. The risk at NAAP is illustrated by the 'pictograms' in Figures 56 through 58. The comparison of risk among the <u>unmitigated</u> alternatives (Figure 56) becomes very obvious

for this site: Continued storage poses the highest risk of all measures. Regional and national disposal represent the least (in fact, very low) risk at NAAP, while the risk due to on-site disposal falls between these extremes. At NAAP, the partial relocation disposal alternative is identical to the on-site disposal alternative.

The major contributions to risk for each unmitigated alternative are discussed below:

- The entire risk associated with continued storage at NAAP is due to external events damaging the stored agent (all of which is agent VX in ton containers in a warehouse.) In particular, the potential accident posing the highest risk, by far, is an earthquake-induced failure of the storage warehouse with a resulting fire. Handling during storage poses only negligible risk.

- For on-site disposal, essentially the entire (all but a fraction of a percent) risk is posed by plant operations, for which the major contributing accident, as with continued storage, is an earthquake-induced failure of the demilitarization building and a simultaneous failure of the fire suppression system.

- The very small risk (**expected fatalities** less than 10^{-4}) of regional and national disposal to the NAAP population is due entirely to a handling accident leading to a short duration fire.

With the introduction of mitigation (see Figure 57), substantial reductions in risk would result for all alternatives. Since the risk for the regional/national alternatives is small to begin with, these alternatives show no substantial benefits of mitigation. The major contributions to risk reduction with mitigation are summarized below:

- For continued storage, mitigation would lead to 98 percent reductions in both **probability of one or more fatalities** and expected fatalities. The reduction in **expected fatalities** is not reflected in the 'pictogram' (Figure 57) because the value of expected fatalities remains greater than the 10^{-2} lower boundary of the highest risk category for that measure. Although the probability of the most severe accident (an earthquake-caused fire) is reduced, the accident is not eliminated. Therefore, there is no reduction in the **maximum number of fatalities** or the **person-years-at-risk** measures. The entire risk contribution remains due to external events.

- For the on-site and partial relocation alternatives, mitigation reduces the **probability of one or more fatalities** by nearly 90 percent. Since the consequences of the most severe accidents

(those caused by aircraft crashes and earthquakes) are not mitigated, there is no reduction in the maximum number of fatalities or the person-years-at-risk measures. The major contribution (~98 percent) to risk, with mitigation, remains the earthquake which damages the plant, leading to a fire.

The introduction of air-space restrictions provides only minor benefit (<2 percent risk reduction) to continued storage and none to the disposal alternatives at NAAP (see Figure 58).

3.3.2.5 Pine Bluff Arsenal (PBA). The risk to the PBA population is portrayed by the 'pictograms' in Figures 59 through 61. The 'pictogram' for the unmitigated case (Figure 59) illustrates a more complex situation than is portrayed for NAAP. On-site disposal appears to pose the highest risk, both in terms of the number of risk measures which are in the higher risk categories, and on the basis of expected fatalities. (As for all sites but APG, LBAD, and TEAD, the programmatic partial relocation alternative calls for on-site disposal at PBA). Continued storage poses the least risk, with the regional/national transportation alternatives responsible for an intermediate level of risk.

Contributions to risk for each unmitigated disposal alternative at PBA are discussed briefly below:

- Over 90 percent of the continued storage risk at PBA results from external events (aircraft crashes or meteorite strikes) causing fire-borne release of mustard agent from the ton containers in open storage. The remainder of the risk is due almost entirely to handling accidents (the dropping of a pallet leading to detonation) affecting stored rockets.

- For on-site disposal, nearly 95 percent of the risk results from plant operations; the remainder is due to on-site transportation. over 90 percent of the plant operations risk is caused by inadvertent feed of rockets and mines to the dunnage incinerator. Rockets and mines, together, are responsible for essentially all of the risk at PBA; bulk containers contribute a negligible fraction (well less than 1 percent).

- For the regional and national disposal alternatives, nearly 60 percent of the risk to the population near PBA results from on-site transportation accidents involving rockets; the remainder of the risk is roughly split between handling and short-term storage, again involving rockets. In fact, all but 2 percent of the risk for all activities is due to rockets. Accidents involving a release of agent GB dominate the risk.

With the introduction of mitigation (revision 1), as shown in Figure 60, the risk of on-site disposal is significantly reduced; mitigation has no effect on the other alternatives at PBA. For the on-site (and partial relocation) alternatives, mitigation reduces the **probability of one or more fatalities** by 98 percent and **expected fatalities** by over 90 percent. Since the consequences of the most severe accidents (a detonation during on-site transportation and earthquake damage to the MDB) are not mitigated, there is no reduction in the **maximum number of fatalities** or **person-years-at-risk**. With mitigation, the major contributor (~85 percent) to risk is the accident resulting in a detonation during on-site transport. Over 95 percent of the risk is due to rockets.

If air-space restrictions (revision 2) were introduced (Figure 61), some reduction in risk would result for continued storage and the regional/national disposal alternatives. The risk reductions are summarized below:

- For continued storage, the **probability of one or more fatalities** is reduced by over 40 percent and **expected fatalities** by ~80 percent. Since the aircrash accidents are not mitigated sufficiently to eliminate them from consideration, the **maximum number of fatalities** and **person-years-at-risk** measures are not affected.

- For the regional/national disposal alternatives, there is no significant reduction in the **probability of one or more fatalities** and only a small (<20 percent) reduction in **expected fatalities**. There is, however, a significant reduction in the **maximum number of fatalities** -- from 40,000 for no air-space restriction to 900 with the restriction. The reduction in **person-years-at-risk** is, similarly, greater than one order of magnitude. This is because the probability of an aircrash accident, which is the most severe accident for these alternatives, has been reduced below 10^{-8} and, thus, screened out of the data base.

3.3.2.6 Pueblo Depot Activity (PUDA). Figures 62 through 64 display, in 'pictogram' form, the comparative risk for the applicable disposal alternatives at PUDA. For the unmitigated case (Figure 62), the continued storage alternative appears to pose the highest risk, but only on the basis of the **probability of one or more fatalities**, relative to the regional and national disposal alternatives. On-site disposal results in the least risk to the population near PUDA if all risk measures are considered. On the basis of **expected fatalities** alone, all disposal alternatives pose low risk (less than 10^{-4}) at PUDA with on-site disposal posing the least.

The factors contributing to unmitigated risk (Figure 62) at PUDA are summarized below:

- The risk at PUDA during continued storage arises entirely from potential aircraft crashes in to the storage facility, leading to detonation and/or fire. Projectiles account for nearly 80 percent of the risk. Although the risk, as measured by expected fatalities is very low, that risk is made up of highly improbable but very severe potential accidents for which the 'no-deaths' plume length, worst-case weather, could exceed 50 km and lead to over 15,000 potential fatalities. The fact that probability of one or more fatalities is relatively high is the result of a single highly probable handling accident of negligible consequence.

- For on-site disposal, plant operations account for nearly 95 percent of the risk, with the major event being earthquake-initiated fires in the munition demil building. The most severe accident involves a 'no-deaths' plume length of approximately 1 km (most-likely weather). The remainder of the risk is due to an on-site vehicle accident leading to detonation and fire.

- The risk at PUDA due to regional and national disposal is entirely the result of short-term storage associated with off-site rail transportation. Most (90 percent) of the risk is due to projectiles. The scenarios contributing the most to risk are those involving aircraft crashes into the transportation containers in the holding area. As with continued storage, the risk as measured by expected fatalities is low but it is comprised of a few high-consequence, low-probability events. The most severe accident leads to a worst-case weather, 'no-deaths' plume length greater than 50 km with the potential to cause over 15,000 fatalities.

Mitigation, with no air-space restriction (Figure 63), results in some risk reduction for the on-site disposal alternative. None of the other alternatives is affected by mitigation. For the on-site (and partial relocation) alternatives, mitigation reduces the probability of one or more fatalities by about 80 percent. Since the consequences of the most severe accidents (externally-initiated plant operations accidents and on-site transport accidents) are not mitigated, there is no reduction in the maximum number of fatalities or person-years-at-risk measures. Most of the risk is attributable to projectiles.

With air-space restrictions (revision 2) (Figure 64), significant reductions in the risk for continued storage and the regional/national alternatives would result. Nevertheless, the factors contributing most to the added risk reduction are summarized below:

- For continued storage, the probability of one or more fatalities would be reduced by over 90 percent and expected fatalities, which are very low to start, would be reduced to well below 10^{-6}. Since

the possibility of the most severe (aircrash) accident is not eliminated (probability reduced to below 10^{-8}) by mitigation, its consequences remain, and the related measures, **maximum number of fatalities** and **person-years-at-risk**, are not affected.

- For the regional/national disposal alternatives, the **probability of one or more fatalities** is reduced by almost two orders of magnitude while **expected fatalities** are reduced to below the 10^{-6} level. The **maximum number of fatalities** is reduced from 16,000, for the case of mitigation, revision 1, to 3 with air-space restriction. **Person-years-at-risk** is similarly reduced by three orders of magnitude (factor of 1000). The reason for the great reduction in these latter two measures is the fact that the probabilities of the most severe accidents (aircraft crashes into the holding areas) have been reduced to below 10^{-8} and, thus, screened out of the accident set defining the alternative. The reason the most severe accidents are eliminated for these alternatives and not for the continued storage alternative is related to difference in target areas in the two cases.

3.3.2.7 Tooele Army Depot (TEAD). Figures 65 through 67 contain the 'pictogram' comparisons of risk measures for TEAD for the the unmitigated case plus two levels of mitigation. For the unmitigated case (Figure 65), continued storage is seen to be the most risky on the basis of all risk measures. The lowest risk alternatives appear to be on-site and regional disposal

The major contributions to risk for the unmitigated alternatives (Figure 65) at TEAD are summarized for each disposal alternative below:

- Over 90 percent of the risk due to continued storage at TEAD is the result of earthquake-initiated damage and/or fire affecting bulk containers of agent VX in warehouse storage. Essentially all of the remainder of the risk is due to handling accidents involving burstered munitions. The events contributing the most to **expected fatalities** are also those having the most severe consequences (**maximum number of fatalities**) as well as a relatively high probability of occurring during the CSDP (10^{-4} to 10^{-3}).

- The risk of on-site disposal at TEAD results from plant operations (57 percent of **expected fatalities**) and handling (42 percent). Nearly half of the risk involves releases from bulk containers or while processing bulk containers, while mines contribute a third of the risk and rockets approximately 10 percent. Over 60 percent of the risk involves agent GB. The scenarios making the major contributions to risk are handling accidents involving ton containers of GB, inadvertent passing of rockets and mines into the

dunnage incinerator, and earthquakes damaging or causing fire in the demil building.

- For regional disposal, 59 percent of the risk comes from plant operations, 27 percent results from handling activities, and 14 percent is due to on-site transportation. Rockets, mines, and bulk containers each contribute about 25 percent to the risk at TEAD. As with on-site disposal, over 60 percent of the risk involves agent GB. Over 40 percent of the regional disposal risk at TE is due to inadvertent feeding of rockets and mines into the dunnage incinerator.

- For national disposal, where the entire U.S. stockpile is disposed of at TEAD, the contribution to total risk due to plant operations rises to 70 percent, with approximately 20 percent of the risk resulting from handling activities and 10 percent caused by on-site transport. Mines and rockets each contribute one-third to the total risk with nearly 20 percent resulting from bulk agent disposal. Slightly more than half of the risk arises from potential accidents involving agent GB. The major scenarios contributing to risk are essentially the same ones responsible for risk for the regional disposal alternative at TEAD, although the relative importance of some of the scenarios is slightly different due to the different mix of munitions in the inventory to be disposed. Nearly 60 percent of the total risk is due to inadvertent feeding of rockets and mines to the dunnage incinerator; handling of ton containers of GB are another major risk contributor -- responsible for 10 - 15 percent of the total. Vehicular accidents during On-site transportation of burstered munitions is next in risk significance.

- For the partial relocation disposal alternatives involving air shipment into TEAD, the risk picture changes significantly. When the C5 aircraft is used (alternative PRA), approximately 3/4 of the risk is due to off-site transportation -- aircraft crashes during landing; most of the remainder of the risk results from plant operations. For the other air-mode alternatives, approximately 1/3 of the risk is due to off-site transportation -- aircraft crashes during landing; most of the remainder of the risk results from plant operations. Rockets are responsible for 50 percent to 75 percent of the total risk; accidents involving bulk containers are next in importance to risk. Close to 80 percent of risk involves agent GB. For the C5 aircraft mode, over 60 percent of the risk results from aircraft crashes on landing while transporting rockets. Aircraft crashes play a much reduced role in TEAD's risk for the other partial relocation alternatives which use the C141 aircraft; for these alternatives, the highest risk event is a handling accident involving ton containers of GB.

Mitigation (revision 1), without air-space restriction (Figure 66), would result in substantial risk reduction for continued storage and all disposal alternatives except for partial relocation for which the risk benefit is less. The major contributions to this risk reduction are summarized below:

- For continued storage, mitigation would reduce the **probability of one or more fatalities** and **expected fatalities** by approximately 98 percent. Since the consequences of the most severe accident (an earthquake-caused storage fire) would not be mitigated, there is no reduction in the **maximum number of fatalities** or **person-years-at-risk** measures. Earthquake-initiated accidents remain the major contributors to risk, accounting for about 90 percent of the total.

- For on-site disposal, mitigation reduces the **probability of one or more fatalities** by about 98 percent. The **maximum number of fatalities** and **person-years-at-risk** measures are not affected since the consequences of the most severe accidents (earthquake-initiated damage to the MDB and a detonation during on-site transport) are not mitigated. Handling accidents account for nearly 75 percent of total risk for this alternative. The remainder of the mitigated risk is due to plant operations and on-site transportation. Handling accidents involving GB are still major contributors to risk -- accounting for nearly 60 percent of the total.

- For regional and national disposal alternatives, mitigation results in a reduction in **probability of one or more fatalities** of 80 percent for regional and nearly 90 percent for national. The reduction for regional disposal is not displayed on the 'pictogram' because both values, unmitigated and mitigated, fall within the risk category range: 10^{-4} to 10^{-3}. As with many other sites and alternatives, the **person-years-at-risk** and **maximum number of fatalities** are not affected by mitigation because the consequences for the most severe accidents (in this case, those involving a detonation during on-site transport) are not mitigated. The accident involving a detonation during on-site transport contributes 45 percent to the overall mitigated risk. The remainder of the risk is due to handling (43 percent) and plant operations (12 percent). Projectiles account for about 50 percent of the risk.

- For the partial relocation disposal alternative, both **probability of one or more fatalities** and **expected fatalities** are reduced by over 50 percent. Although this is a small change, well under an order of magnitude, it is reflected in the 'pictogram' because both values happen to cross over the boundaries defining their shading (risk measure) categories. The consequences of the most severe accident (crash of an aircraft carrying burstered munitions or a

detonation during on-site transport) are not mitigated, so there is no reduction in maximum number of fatalities or person-years-at-risk for this alternative. Mitigation has the effect of increasing the relative contribution of the aircraft crashes to risk -- to over 80 percent of the total. Rockets account for 80 percent of the mitigated risk.

The introduction of air-space restrictions (Figure 68) will have no significant impact on risk at TEAD for any alternative because of the relatively low aircraft traffic density over TEAD.

3.3.2.8 Umatilla Depot Activity (UMDA). The 'pictograms' comparing risk measures among the applicable disposal alternatives at UMDA for the unmitigated case plus two mitigation levels are presented in Figures 68 through 70. The only obvious conclusion to be drawn from Figure 68, for the unmitigated alternatives, is that the risk due to continued storage exceeds that of any of the disposal alternatives, both in terms of the number of risk measures (all) for which risk is in the maximum category and in terms of expected fatalities. In fact, the risk of continued storage for 25 years, as measured by expected fatalities, dominates disposal risk by several orders of magnitude.

The major contributions to unmitigated risk (Figure 68) for each disposal alternative are summarized below:

- The risk associated with continued storage is due almost entirely (>99 percent) to earthquake-induced damage with fire in warehouses storing mustard ton containers. This scenario represents a set of potential accidents with probabilities in the range of 10^{-6} to 10^{-4} per year and 'no-deaths' plume lengths of 20 - 30 km, for most-likely weather, and 200 - 300 km, for worst-case weather; potential fatalities exceed 400 for average conditions and approach 50,000 for extreme conditions (worst-case weather and wind direction over peak population density).

- For on-site disposal, plant operations accidents contribute over 90 percent of the total risk; on-site transportation accidents are responsible for most of the remainder. Two-thirds of all risk is due to rockets, with the remainder resulting from the disposal of mines. The inadvertent feeding of rockets and mines to the dunnage incinerator accounts for over 80 percent of the total risk for this alternative; on-site vehicle accidents and earthquake-initiated fire in the demil building during the processing of rockets and mines account for nearly all the remainder of the identified risk. Agent GB is involved in most of the risk; mustard-related accidents are negligible for plant operations (whereas mustard dominates for

storage-related accidents because a much larger source of agent is available for release).

- The risk due to national and regional disposal, as measured by **expected fatalities**, is quite low (less than 10^{-4}) and arises mostly from on-site transportation accidents; short-term storage and handling accidents also make a significant and equivalent contribution to risk. Again, approximately 90 percent of the risk is GB-related, with rockets making the dominant contribution; bombs are responsible for most of the remainder of the identified risk. The scenarios contributing most to risk are a severe on-site vehicle transporter accident, an aircraft crash into the holding area during short-term storage, and a handling accident leading the drop and detonation of a palletized rocket.

When mitigation (revision 1) is introduced (Figure 69), the risk of continued storage and on-site disposal are significantly reduced. The regional and national alternatives are not significantly affected. The details of the risk reductions are summarized below:

- For continued storage, both the **probability of one or more fatalities** and the **expected fatalities** measures are reduced by about 98 percent. The reduction in **expected fatalities** is not reflected in the 'pictogram' (Figure 69) because even the mitigated value for **expected fatalities** remains above the break point -- 10^{-2}. Again, the consequences of the most severe accidents (earthquake-induced warehouse fires and an aircraft crash into a warehouse) are not involved in the mitigation process, and the result is no change in the **maximum number of fatalities** and **person-years-at-risk** measures. With mitigation, the risk remains almost entirely due to earthquake-induced warehouse fires.

- For the on-site and partial relocation alternatives, mitigation leads to a factor of 10 reduction in **probability of one or more fatalities** and **expected fatalities**. The most severe accident (a large aircraft crash onto the MDB) has not been mitigated, leading to no reduction in **maximum number of fatalities** and **person-years-at-risk**. Approximately 70 percent of the mitigated risk results from an accident involving a detonation during on-site transport; the remainder is due to plant operations (17 percent) and handling (12 percent). Agent GB is involved in accidents accounting for 80 percent of the mitigated risk.

If air-space restrictions were to be introduced (Figure 70), there would be a slight benefit to the rail-mode colocation alternatives. No significant benefit would accrue to the other alternatives. The rail-mode

risk benefits consist of a reduction in **expected fatalities** by 28 percent and a 10-fold reduction in **maximum number of fatalities**, from 24,000, for no air-space restriction, to 2500 with the restriction; **person-years-at-risk** would be reduced by nearly 56 percent. These reductions flow from the fact that the probability of the most severe accident (a large aircraft crashing into the holding area) is reduced to below 10^{-8} and is thereby screened out of the active data base for this alternative.

3.3.2.9 Transportation Corridors - Regional (Rail) Alternative. Figure 44 summarizes, in 'pictogram' form the risk measures along the regional (rail) transportation corridors. The rail corridors from LBAD, PBA, and UMDA pose the highest risk in terms of **expected fatalities**. For these three corridors, rockets are responsible for well over half of the risk. For the other corridors (originating from APG, NAAP, and PUDA), the risk is lower primarily because rockets are not a part of the transported stockpile. The risk-dominating accident scenarios are severe train accidents with fire of long enough duration to cause failure of the overpack and the munitions (either by burster detonation or by thermal rupture of bulk containers). The applicable scenario (depends on whether the transported inventory is burstered or not) accounts for at least 95 percent of the risk (>99 percent for three sites) in all corridors.

The most severe potential accidents are those in the LBAD, PBA, and UMDA corridors. They yield worst-case 'no-deaths' plume lengths in the range of 15 to 20 km and could cause, under extreme conditions, 1000 to 2000 potential fatalities.

3.3.2.10 Transportation Corridors - National (Rail) Alternative. The risk picture is much the same for national disposal as it is for regional, as seen in Figure 45. The major difference is due to the fact that the ANAD stockpile is now transported to TEAD and, because of the size and composition of the ANAD stockpile, the risk in the ANAD - TEAD corridor dominates. In addition, selected risk parameters for APG, LBAD, and PBA are higher for national than for regional, primarily because of the greater travel distance for these stockpiles. For the ANAD - TEAD corridor, virtually all of the risk is associated with the movement of energetic munitions; the largest contribution to risk results from the transporting of projectiles, with the risk due to rockets not far behind.

The scenarios contributing the most to risk are the same severe rail accidents, with long-duration fires, that control risk for the regional corridors. The highest-consequence accident for the ANAD - TEAD corridor is expected to cause a worst-case 'no-deaths' plume length of 19 km with the potential for over 6000 fatalities.

3.3.2.11 Transportation Corridors - Partial Relocation Alternative. The risk along the transportation corridors that might be employed during the partial relocation disposal alternative is depicted in Figure 38 and, for the additional air- and water-mode alternatives, in Figure 24b. The route emanating from LBAD represents significantly higher risk than those originating from APG. The water mode from APG to JI (Johnston Island) appears to pose very low risk to the public. However, it should be noted that the transportation corridor accidents for this mode do not include the accident scenarios which have been identified for the barge (or 'lighter') portion of the trip (from a dock at APG to the moored LASH vessel in the bay) nor do they include those events that could happen while the LASH is still at anchor. Lastly, between the two aircraft options (C5 vs C141), the C141 contributes the lesser risk to the public.

The major contributors to risk along the two corridors are discussed briefly below:

- For the LBAD - TEAD Corridor, via air mode, the risk (when measured, as before, by **expected fatalities**) associated with the use of the C5 aircraft is nearly a factor of 10 greater than for the C141 aircraft. For both aircraft options, 90 percent of the risk results from the transport of rockets; the rest is due to projectiles. Accidents involving GB constitute over 80 percent of the total corridor risk in both cases. Better than 75 percent of the risk results from a severe potential crash on an aircraft carrying GB-filled rockets; the accident would be sufficient severity as to rupture both the shipping containers and the munitions, with a possible fire. These high risk accident scenarios also represent the most severe consequence as well: worst-case 'no-deaths' plume lengths of 64 and 31 km for the C5 and C141 options, respectively, with maximum potential fatalities of 73,000 and 23,000, also respectively.

- The risk along the APG - TEAD Corridor, via air mode, is also nearly a factor of 10 higher for the C5 aircraft option. The three scenarios contributing to risk in this corridor all involve severe aircrashes with breach of the shipping container and the agent containers. Worst-case plume lengths are considerable smaller than for the LBAD stockpile -- 5.2 and 2.3 km for the C5 and C141, respectively; maximum potential fatalities for these worst cases are 7500 and 3500, respectively.

- Along the APG - JI Corridor, via water mode, all identified accidents have both low probabilities and moderately low consequences. Probabilities are all in the range of 10^{-7} to 10^{-5}, and worst case plume lengths are less than 7.5 km -- too small to reach major population groups according to the fatality-estimating data tables in Appendix C (see Volume 2 of this report).

For all the transportation corridors, the effects of the mitigation measures are negligible -- certainly not enough to alter the 'pictogram' portrayal, a fact noted on Figures 36 through 38. Mitigation, revision 1 (no air-space restriction) yields, at best, a small reduction (less than 20 percent) in both expected fatalities and probability of one or more fatalities for the APG - TEAD air corridor. Air-space restrictions, as expected, would offer no additional benefit to any of the transportation corridors.

3.4 Individual Risk

Three of the risk measures identified in section 2.3 are indicative of individual risk: **maximum individual risk**; **maximum lethal distance**; and, time-at-risk. The data for determining the first two measures are obtained directly from the computation of curves showing individual risk as a function of the individual's distance from a potential accident site. Because presentation of the actual data is both site- and disposal alternative-specific, the presentation of the individual risk curves could reveal sensitive information regarding the stockpile inventory at each site. The individual risk curves are presented in volume 3 (classified) of this report. Although it is a measure of individual risk, time-at-risk is discussed separately in section 3.5.1 under the category of time-related risk measures.

A typical individual risk curve is shown in Figure 71. An individual living near a particular site can interpret his individual risk from such a curve in the following way. The vertical scale of the figure displays the probability of that individual's death during the course of the CSDP activities at the site (3 to 5 years for the disposal alternatives; 25 years for the continued storage option). The curves show that the individual's risk decreases steadily as his distance from the site (as read on the horizontal scale of the graph) increases. The minimum distance shown is 0.5 km, which, by assumption imposed on the analysis, is the minimum distance from chemical operations to the site boundary for any of the disposal/storage sites. Thus, the risk given by the figure is the maximum off-site (public) risk only. (Risk to on-post personnel is not within the scope of this analysis.)

Interpretation of the individual risk curve will proceed as follows. Consider first an individual who spent the entire duration of the CSDP located at the boundary of the site (at 0.5 km). For the applicable disposal alternatives, that individual would experience a chance of death during the CSDP of the value given by the vertical scale of the figure. If the individual lives farther away from the site center, his risk becomes progressively lower until finally the individual is beyond the point where

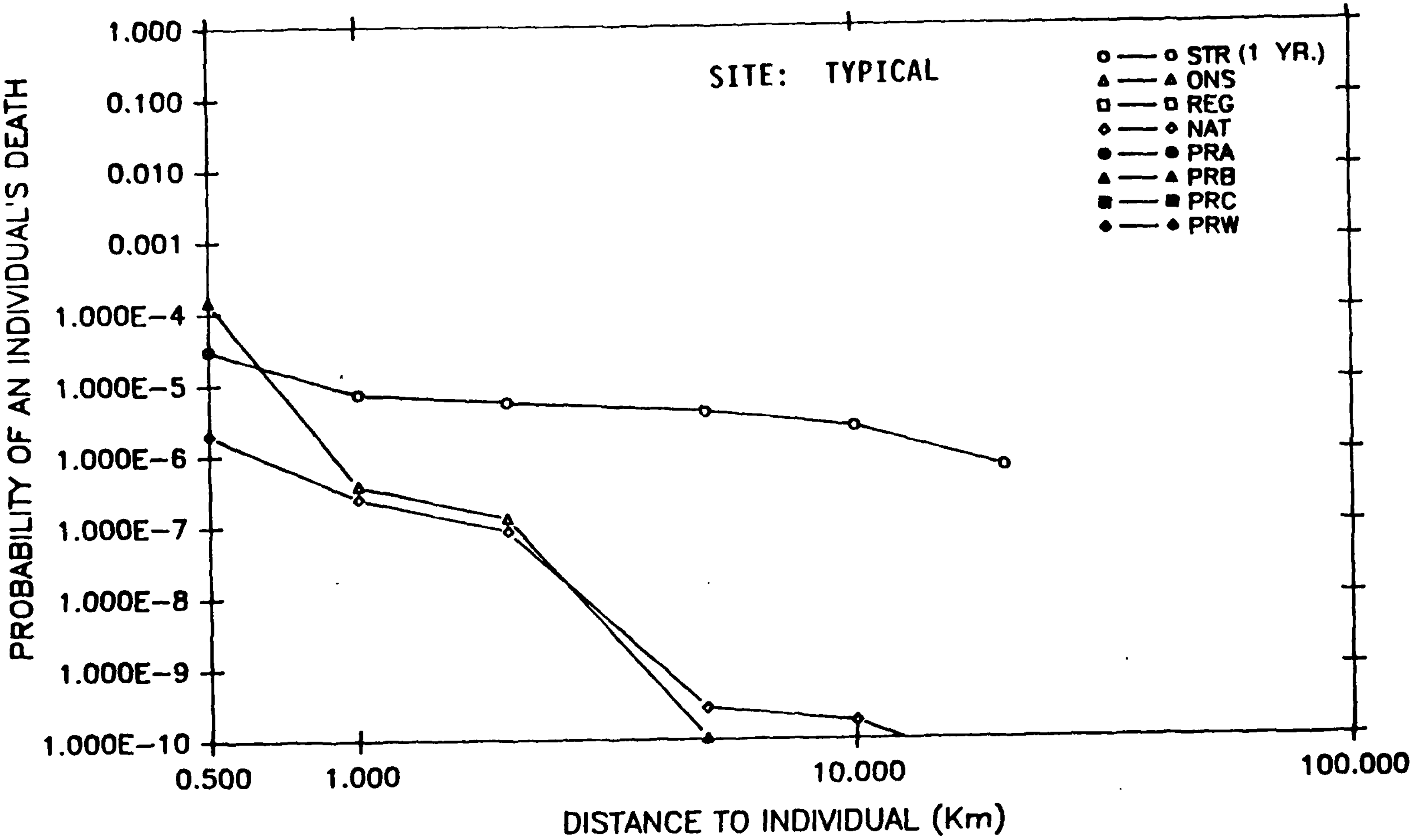


FIGURE 71

INDIVIDUAL RISK AT FIXED SITES

the most severe accident is expected to cause any lethal impact and his risk of death becomes zero. The individual risk value at 0.5 km is the principal risk measure: **maximum individual risk**. The distance beyond which no lethal effects are expected for any applicable accident is the maximum lethal distance under most-likely meteorological conditions; not shown is the other major risk measure for individual risk -- the **maximum lethal distance** which, as noted earlier, is based on the assumption of extreme conditions (meteorology, wind direction, and population density).

Individual risk varies widely from site to site and among the disposal alternatives. The regional and national disposal sites, TEAD and ANAD, pose highest risk to an individual on the basis of **maximum individual risk** (probability of an individual's death during the CSDP when at the assumed 0.5 km site boundary -- see section 4.2.2 for a discussion of the effects of site boundary assumptions). On the basis of **maximum lethal distance** (the farthest plume reach of any identified accident under the worst-case meteorology), individual risk is highest at PBA, PUDA, and UMDA for the national and regional alternatives. For these three sites, the worst case hazard distance is the result of an aircraft crash into the short-term storage (holding) area while awaiting rail shipment. The fact that these scenarios do not pertain to other sites is due to the elimination of all accident scenarios for which the probability of occurrence during the CSDP is less than 10^{-8}. Since **maximum individual risk** incorporates probability data in its determination, it may be the preferred measure for individual risk, if only one measure were to be used.

In contrast to the individual risk data for a fixed site, risk to an individual along transportation corridors is calculated to within 0.1 km of the corridor centerline; the individual risk at this minimum distance is the value used in determining maximum individual risk for alternatives including off-site transportation. **Maximum individual risk** is negligible (less than 10^{-8}) along all the transportation corridors -- a conclusion consistent with the relatively low individual time-at-risk values discussed in section 3.5.1 below. However, **maximum lethal distance** values are not negligible for the transportation corridors and, in fact, for the LBAD - TEAD corridor (C5 aircraft), can exceed 50 km.

3.5 Time and Person-Years at Risk

The individual risk data discussed in section 3.4 accounts for the time during which an individual is exposed to risk from accidental chemical agent release. As described in Appendix A, individual risk considerations also account for the probability of individual accident scenarios occurring as well as the severity of the release (i.e., the position of the individual within the plume) and the likelihood that meteorological conditions (i.e., wind direction) will cause the plume to move over the individual.

However, for many individuals, the concept of individual risk may be more easily understood in terms of the individual's **total time of exposure** to risk, regardless of whether his/her actual risk varies during that period or is comparable to the actual risk borne by others. Accordingly, two time-related risk measures are addressed in this section:

- The total **time-at-risk** during the CSDP when an individual could be exposed _if_ an accident were to occur;

- The total **person-years-at-risk** during the CSDP -- a measure equal to the time-at-risk times the number of people experiencing any risk (i.e., being within a zone that could encompass potentially lethal exposures, as defined by the 'no-deaths' plume length under worst-case meteorological conditions).

3.5.1 Time-at-Risk

Time-at-risk is readily addressed at the storage/disposal sites since the appropriate time measure is simply the duration of disposal activities at a given site. These times vary from less than 1 year to over 4 years, depending on the site. The actual disposal duration time at a given site cannot be stated because of the possibility of revealing classified data regarding stockpile size. By this measure, all individuals within a distance equal to the maximum possible (worst-case weather) 'no-deaths' plume length from a specific site should be considered 'at risk' for the same duration of time; outside this site-specific maximum distance, time-at-risk would be zero. Table 2 lists these maximum (worst-case) distances for each site and each applicable disposal alternative, in the unmitigated case. An individual located within the stated distance of a given site could assume his/her time-at-risk to be the duration of disposal activity for a given disposal alternative. Table 3 displays the same information for the case of accident mitigation, including airspace restrictions (mitigation of accidents other than airspace restriction did not significantly affect maximum consequences, of the accidents treated).

Along transportation corridors, time-at-risk for an individual is dependent on the individual's location -- his/her distance from the transportation corridor. Table 4 (data same for unmitigated and mitigated with airspace restriction) lists the maximum worst-case plume lengths for the transportation corridors.

Figures 72 and 73 show time-at-risk along rail and air transportation corridors, respectively, in terms of hours of exposure per vehicle trip as a function of an individual's distance from the centerline of the corridor and the severity (worst-case 'no-deaths' plume length) of the worst identified potential accident for a given corridor (as determined from

TABLE 2
MAXIMUM (WORST-CASE) HAZARD DISTANCES -- STORAGE/DISPOSAL SITES
- UNMITIGATED -

SITE	MAXIMUM (WORST-CASE) HAZARD DISTANCE (km) -- for a given Disposal Alternative --							
	STR	ONS	REG	NAT	PRA	PRB	PRC	PRW
ANAD	150.4	32.9	28.2	27.9	32.9	32.9	32.9	32.9
APG	17.4	4.4	44.6	44.6	11.5	11.5	76.7	76.7
LBAD	4.6	17.5	14.9	14.9	64.0	30.8	30.8	17.5
NAAP	304.2	15.5	6.1	6.1	15.5	15.5	15.5	15.5
PBA	85.2	32.9	183.8	183.8	32.9	32.9	32.9	32.9
PUDA	56.2	4.3	75.9	75.9	4.3	4.3	4.3	4.3
TEAD	108.0	32.9	27.9	27.9	64.0	32.9	32.9	32.9
UMDA	314.0	28.2	150.8	150.8	28.2	28.2	28.2	28.2

* * * * * * * *

TABLE 3
MAXIMUM (WORST-CASE) HAZARD DISTANCES -- STORAGE/DISPOSAL SITES
- MITIGATED WITH AIRSPACE RESTRICTION -

SITE	MAXIMUM (WORST-CASE) HAZARD DISTANCE (km) -- for a given Disposal Alternative --				
	STR	ONS	REG	NAT	PRB
ANAD	5.4	32.9	28.2	27.9	32.9
APG	17.4	4.4	2.1	2.1	2.3
LBAD	4.6	17.5	14.1	14.1	30.8
NAAP	304.2	12.9	6.1	6.1	12.9
PBA	85.2	32.9	14.1	14.1	32.9
PUDA	56.2	4.3	7.3	7.3	4.3
TEAD	108.0	32.9	27.9	27.9	32.9
UMDA	314.0	27.9	19.1	19.1	27.9

* * * * * * * *

TABLE 4
MAXIMUM (WORST-CASE) HAZARD DISTANCE -- TRANSPORTATION CORRIDORS
- MITIGATED AND UNMITIGATED CASES -

ORIGINATING SITE	MAXIMUM (WORST-CASE) HAZARD DISTANCE (km) -- for a given Disposal Alternative -- REG	NAT	PRB
ANAD	*****	19.1	*****
APG	2.3	2.3	2.3
LBAD	16.5	16.5	30.8
NAAP	8.6	8.6	*****
PBA	19.1	19.1	*****
PUDA	3.8	3.8	*****
UMDA	19.1	19.1	*****

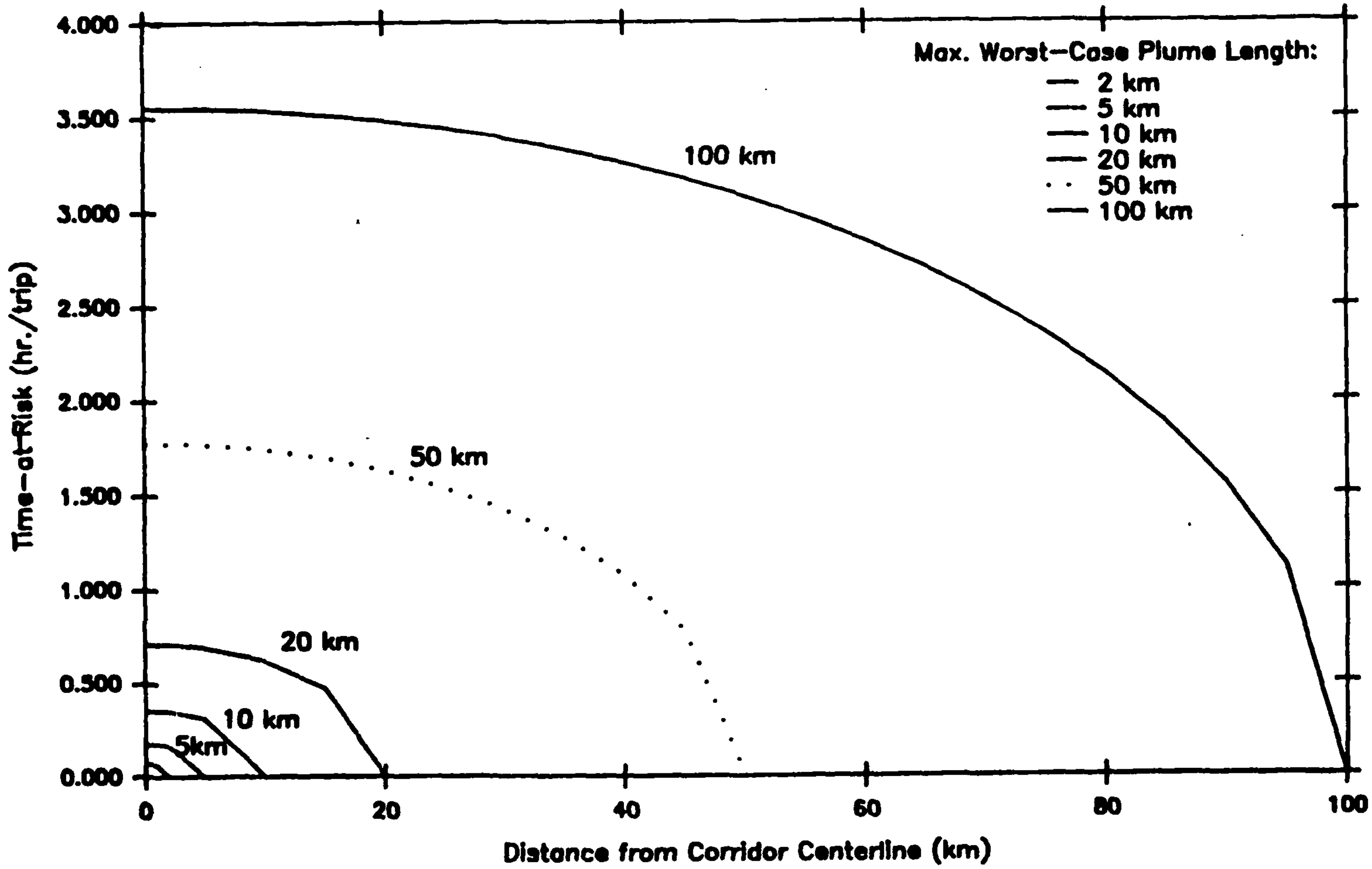


FIGURE 72

TIME-AT-RISK – RAIL CORRIDORS
Hr. per trair ‥ip (35 mph)

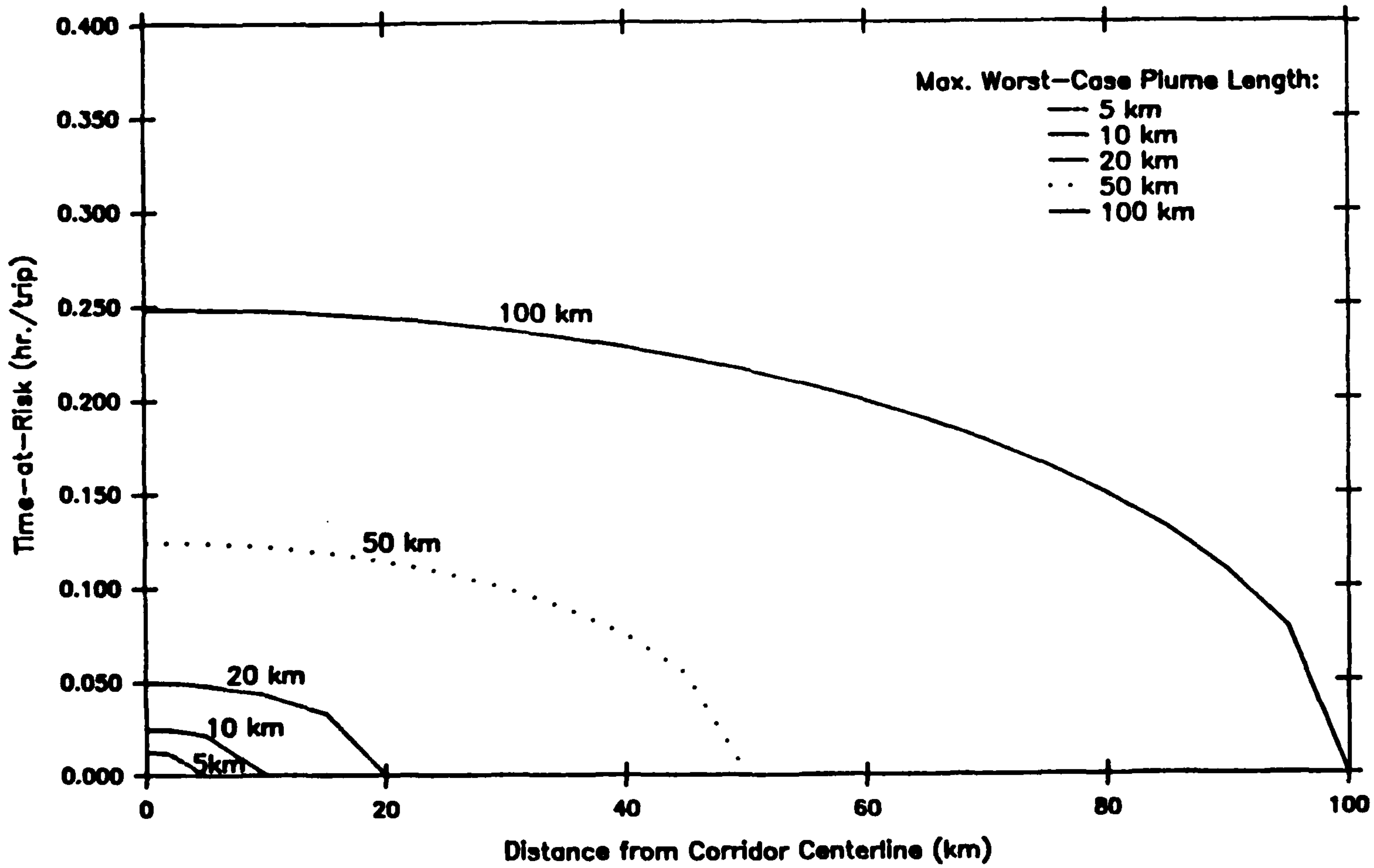


FIGURE 73

TIME-AT-RISK -- AIR CORRIDORS
Hr. per aircraft trip (500 mph)

Table 4, unmitigated and mitigated cases). To determine his/her time-at-risk for a given disposal alternative, an individual would need to do the following:

- identify which site stockpiles are to be transported along his/her portion of the corridor;

- determine the number of transporter trips (number of train-trips or aircraft-trips) required to move the stockpile for each site;

- estimate, with the aid of Table 4 and Figures 72 and 73, the time-at-risk per trip from each site;

- calculate the sum of total time-at-risk by the relation:

$$\text{TOTAL TIME-AT-RISK, } T = \sum_{\text{all sites}} (\text{time/trip})_{\text{site } j} * (\text{trips/stockpile})_{\text{site } j}$$

An approximate upper limit can be set on time-at-risk for both fixed site and transportation corridors:

- For fixed sites, the maximum time-at-risk is in the range of 4 years (35,000 hrs);

- For the regional (rail) corridors, the maximum number of trains is approximately 50, and the maximum hazard distance is in the 20 km range; an individual living within 10 km of the track carrying all 50 (or so) trains would experience a total time-at-risk of:

  MAX. TIME-AT-RISK (REG) = (0.7 hr/train) * (50 trains)
  = 35 hr

- For the national (rail) corridors, the maximum hazard distance is also approximately 20 km. The maximum number of trains for this alternative is approximately 75, leading to:

  MAX. TIME-AT-RISK (NAT) = 53 hr

- For the partial relocation (air-mode) corridor, the maximum hazard distance is approximately 31 km, leading to a time-at-risk of approximately 0.07 hr/aircraft flight. The actual number of flights required to move the APG and LBAD stockpiles is classified; but, it can be said to be in the range of 900 - 1200 air-lifts for the APG stockpile and in the range of 1200 - 1500 air-lifts for the LBAD stockpile, yielding a total number of airlifts in the range

of 2100 - 2700 for the combined air-lifted stockpile. Using 2500 air-lifts (which could consist of several flights each, but would not thereby add to an individual's time-at-risk) as as a rough indicator of air traffic intensity, we find that:

MAX. TIME-AT-RISK (AIR MODE) = (0.07 hr/flight) * (2500 flights) = 175 hr

Thus, the time-at-risk for individuals along the transportation corridors is in the range of 100 hr. For individuals around a disposal site, time-at-risk is measured in the tens-of-thousands of hours -- a hundred-fold greater time than for those along the corridors.

3.5.2 Person-Years-at-Risk

The societal counterpart to the individual's time-at-risk measure discussed above is the number of person-years-at-risk. Although the time-at-risk for an individual along a transportation corridor is low (by a factor of 100 to 1000) compared to that for individuals about storage/disposal sites, the number of individuals experiencing that time-at-risk is greater (by a factor of roughly 10) along the corridors. Hence, risk, as measured by person-years-at-risk tends to be more evenly shared between fixed site and corridor population groups, although the former group's share is still the greater, by far.

The population data used to estimate potential fatalities among all population groups potentially affected by the CSDP can also be used to estimate person-years-at-risk for each exposed population group and for each disposal alternative. The results of that analysis are displayed in Tables 5 and 6.

With the aid of Tables 5 (for the cases of no mitigation or mitigation without air-space restrictions) and 6 (mitigation with air-space restrictions), one can compare the person-years-at-risk for all locations (fixed sites as well as transportation corridors) for all the CSDP alternatives, including 25 years of continued storage; the dominance of risk posed by continued storage is clear. Among the disposal alternatives, on-site disposal poses the least risk while national disposal represents the highest value for person-years-at-risk. Examining person-years-at-risk along the transportation corridors for the various transportation alternatives, one can see that the rail mode alternatives are significantly less risky than the air modes, according to this measure, with regional (rail) responsible for the least person-years-at-risk. The principal reason for the four-fold difference between regional and national is the transportation of the Anniston stockpile for the national alternative.

TABLE 5
PERSON-YEARS-AT-RISK -- NO AIR-SPACE RESTRICTION

- Fixed Sites -

SITE\ALT:	STR	ONS	REG	NAT	PRB
ANAD	37759175	650156	1147150	1094013	650156
APG	4975700	22910	975776	975776	398056
LBAD	59525	50579	82466	82466	409223
NAAP	28331075	38242	4509	4509	38242
PBA	20216050	1049458	1617284	1617284	1049458
PUDA	12486100	97	749166	749166	97
TEAD	24203400	113982	132979	132979	132979
UMDA	7794550	340930	779455	779455	340930
TOTAL	135825575	2266353	5488785	5435647	3019140

- Transportation Corridors -
(Originating at Specified Sites)

SITE\ALT:	REG	NAT	PRB
ANAD	0	8642	0
APG	263	307	504
LBAD	1884	2923	61522
NAAP	180	282	0
PBA	1177	1277	0
PUDA	65	65	0
UMDA	279	279	0
TOTAL	3849	13777	62026

- All Locations Combined -

SITE\ALT:	STR	ONS	REG	NAT	PRB
ANAD	37759175	650156	1147150	1102654	650156
APG	4975700	22910	976039	976083	398560
LBAD	59525	50579	84350	85389	470745
NAAP	28331075	38242	4689	4791	38242
PBA	20216050	1049458	1618461	1618561	1049458
PUDA	12486100	97	749231	749231	97
TEAD	24203400	113982	132979	132979	132979
UMDA	7794550	340930	779455	779455	340930
TOTAL	135825575	2266353	5492354	5449144	3081166

TABLE 6
PERSON-YEARS-AT-RISK -- WITH AIR-SPACE RESTRICTION

- Fixed Sites -

SITE\ALT:	STR	ONS	REG	NAT	PRB
ANAD	462525	650156	1147150	1094013	650156
APG	4975700	22910	6260	6260	25038
LBAD	59525	50579	82466	82466	409223
NAAP	28331075	38242	4509	4509	38242
PBA	20216050	1049458	150488	150488	1049458
PUDA	12486100	97	626	626	97
TEAD	24203400	113982	132979	132979	132979
UMDA	7794550	340930	340930	340930	340930
TOTAL	98528925	2266353	1865407	1812269	2646122

- Transportation Corridors -
(Originating at Specified Sites)

SITE\ALT:	REG	NAT	PRB
ANAD	0	8642	0
APG	263	307	504
LBAD	1884	2923	61522
NAAP	180	282	0
PBA	1177	1277	0
PUDA	65	65	0
UMDA	279	279	0
TOTAL	3849	13777	62026

- All Locations Combined -

SITE\ALT:	STR	ONS	REG	NAT	PRB
ANAD	462525	650156	1147150	1102654	650156
APG	4975700	22910	6523	6567	25542
LBAD	59525	50579	84350	85389	470745
NAAP	28331075	38242	4689	4791	38242
PBA	20216050	1049458	151665	151765	1049458
PUDA	12486100	97	690	690	97
TEAD	24203400	113982	132979	132979	132979
UMDA	7794550	340930	340930	340930	340930
TOTAL	98528925	2266353	1868976	1825766	2708148

The distribution of person-years-at-risk among the eight storage/disposal sites can be compared for the various CSDP alternatives. For continued storage, ANAD displays the highest value of person-years-at-risk, with APG and LBAD having the least risk by this measure. Person-years-at-risk resulting from on-site disposal are greatest at PBA, ANAD, and UMDA, in decreasing order, and least at PUDA, APG, NAAP, and LBAD, in increasing order. The distribution of person-years-at-risk about the fixed sites is, as expected, identical for the regional and national alternatives -- the only exception being ANAD for which the difference between alternatives is approximately 5 percent. The partial relocation alternative (air mode) affects only three sites, but the major impact is felt only at APG and LBAD.

Looking at th transportation corridors for the rail- and air-mode alternatives, one can readily see the relatively high risk, as measured by person-years-at-risk, of moving the ANAD stockpile; the next risky stockpile move is that of the LBAD stockpile. However, the highest number of person-years-at-risk along any corridor results from the air movement of the LBAD stockpile -- the reason being the composition of the LBAD stockpile and the the fact that it, unlike the APG stockpile for which air-mode corridor risk is negligible, is comprised of energetic munitions.

4.0 DISCUSSION OF RESULTS

4.1 Statistical Significance of Differences in Risk

The probability that the risk (in terms of expected fatalities) of any programmatic alternative exceeds the risk of any other alternative is shown in Table 7. It should be noted, however, that a number of uncertainties (some of which are discussed above, in section 3.2.2, and below, in section 4.2) were not explicitly considered in the development of the accident scenario data base used to compute these results. Therefore, it should be understood that the probabilities shown in Table 7 overstate the certainty of risk differences; that is, all of the probabilities should be somewhat closer to 50 percent. More specifically, probabilities in the range of roughly 30 percent to 70 percent do not substantiate true differences in risk, while probabilities below 30 percent or above 70 percent do indicate the likelihood of actual differences in risk.

The main conclusions that may be drawn from Table 7, for the case of unmitigated risk, are the following:

- Storage for 25 years (STR) is the riskiest alternative;
- Partial relocation alternatives involving air transport (PRA, PRB, and PRC) are next riskiest. Of these, PRA (based on use of the C5 aircraft) is the riskiest. On the other hand, the risks of PRB and PRC are indistinguishable from the risk of national (NAT) and regional (REG) relocation by rail.
- National (NAT) and regional (REG) relocation by rail, partial relocation by water (PRW), and on-site disposal (ONS) are the least risky alternatives. Within this group, overall risks are indistinguishable.

4.2 Caveats and Limitations

4.2.1 Frequency and Consequence Screening

The accident scenario data base for this risk analysis was screened so that only those accidents with a potential (under worst-case meteorology) for causing fatalities beyond the installation boundaries (assumed to be 0.5 km for all sites) and having a probability of occurring during the course of the CSDP (or during a one-year period, in the case of continued storage activities) of at least 10^{-8} are included.

TABLE 7

PROBABILITY OF RISK DIFFERENCES BETWEEN ALTERNATIVES [percent]*
- Unmitigated Risk -
[Risk measured by **Expected Fatalities**]

	STR	ONS	REG	NAT	PRA	PRB	PRC	PRW
STR	--	99	99	99	99	99	99	99
ONS	1	--	48	37	1	6	6	49
REG	1	52	--	37	15	35	35	52
NAT	1	63	63	--	26	49	49	63
PRA	1	99	85	74	--	81	81	99
PRB	1	94	65	51	19	--	69	94
PRC	1	94	65	51	19	31	--	95
PRW	1	51	48	37	1	6	5	--

----

* Example: The probability that PRA (in row 5) is riskier than NAT (in column 4) is 74 percent (value in row 5, column 4). Conversely, the probability that NAT (in row 4) is riskier than PRA (in column 5) is 26 percent. Note that the two results, 74 percent and 26 percent, are complementary and total 100 percent. Thus, the "odds" that PRA is riskier than NAT are 74:26, or about 3:1. These results are based on comparisons of the means and ranges of computed "expected fatalities," after eliminating accident scenario contributions common to the two alternatives being compared (in order to obtain independently distributed data). Note that, since some types of uncertainty have not been considered explicitly, mid-range probabilities (e.g., those between 30 percent and 70 percent) are not believed to substantiate conclusions that risks are different.

4.2.2 Potential Fatality Estimates and Site Boundaries

The fatality estimates used in the risk analysis were computed by Oak Ridge National Laboratories (ORNL) using population data from census tracts. It is not possible from such data to determine the precise location of populations. Since the risk analysis is concerned with the potential health effects to the general population located outside the military reservations, personnel within the boundaries of the reservations should not be considered. In an effort to exclude these personnel from consideration, ORNL set all fatality rates to zero for distances of up to 0.5 km from the disposal or storage site where accidents may occur. Thus, no fatalities are computed for low-consequence accidents for which the zero-fatalities distance does not exceed 0.5 km, if the accidents occur within a military reservation.

Using 0.5 km as a cut-off distance for fatality computations is a conservative approach; i.e., the number of fatalities may be overstated. This is because the actual distances from disposal and storage sites to military reservation boundaries range from 0.9 to 3.5 km. Thus, if the actual boundaries had been used to compute the number of fatalities, the value of "expected fatalities" would have been substantially lower in a number of cases. The most significant reduction (about an order of magnitude) in "expected fatalities would be for the on-site disposal alternative at Anniston, Aberdeen, Pine Bluff, Tooele, and Umatilla. The total of expected fatalities at all sites for the on-site alternative would be approximately 75 percent lower.

4.2.3 Impacts of Mitigation

The impacts of the mitigation effort on comparative risk are substantial. The introduction of these mitigation measures is predicted by the risk analysis to lead to substantial reductions in the risk associated with the on-site alternative -- so much so that, on the basis of an assessment of statistical significance of risk differences, it appears that on-site risk will be less risky than that due to any of the relocation alternatives, including the rail modes. However, the dunnage furnace accident is, for some sites, still a dominant contributor to risk (expected fatalities); the reason for the continuing dominance is the fact that the other high risk accidents were mitigated at the same time, so the dunnage furnace accidents, now in the probability range of 10^{-5} to 10^{-6}, still play a significant role relative to a much smaller base.

APPENDIX A

GENERAL APPROACH TO THE RISK ANALYSIS

APPENDIX A: GENERAL APPROACH TO THE RISK ANALYSIS

A.1 Introduction

The purpose of this section is to provide an overview of how the risk analysis was conducted, to describe the flow and management of data, and to introduce the basic elements of the risk analysis methodology. The details of how critical portions of the methodology were developed and applied to the accident scenario data base, such as the estimation of consequences (plume lengths and potential fatalities) and the treatment of uncertainty, are explained in Appendix B. We begin this appendix with a description of the concepts involved in the computation of risk; we follow this with a brief description of the accident scenario data base; we then describe the process of integrating the accident scenario data with population data and the Army's proposed Chemical Stockpile Disposal Program description to produce an integrated assessment of the risk associated with the several CSDP disposal alternatives.

A.2 Application of Risk Concepts to the CSDP

A.2.1 Computation of Individual Risk (General Case)

As described earlier, the risk to an individual is calculated by multiplying together the probabilities of each of the circumstances necessary to produce a fatality. This combined probability of occurrence is multiplied times the consequence to determine risk; in the individual case, consequence is always equal to 1 (the death of the individual), and so does not affect the risk value we calculate. Figure 3 (in the main body of the report) illustrates the major factors affecting the risk to an individual posed by the CSDP. First of all, there is the probability that an accidental release occur; we will represent this value by the symbol, P_A. If the accident involves a transportation accident (a train is shown for illustration), then we must include the probability that the transport vehicle will be close enough to harm the individual when the accident occurs; call this probability, P_T. For the sake of this illustration, we will assume it has a value of 1. (Risk along a transportation route will be discussed in more detail below.) Now, given that there is a probability, $P_A \times P_T$, of accidental agent release in the vicinity of the individual, the next factor affecting the individual's risk is whether he is downwind of the accident. Assuming for the moment that the wind has equal probability of blowing from any of the 16 compass point directions (N, NNE, NE, ENE, etc.), then the probability of being downwind of the release can be represented by P_W, which has a value of 1 in 16, or approximately 0.06. The width of the potentially lethal portion of the atmospheric plume is approximately one-third of a compass sector. Therefore, if the individual is "downwind" of the accident, the probability

of being within the plume width, P_P, is about 1 in 3, or 0.3. Finally, the individual must be close enough to the accident site so that potentially lethal dosages could reach him. "Close enough" in this case is determined by the atmospheric plume dispersion analysis. It is defined as the downwind distance to the "no-deaths" dosage for whatever chemical agent is involved. Since dosage increases as the individual is closer to the accident site and closer to the centerline of the agent plume, the probability of a fatality for an individual within the plume, P_L, which ranges from a value of 0 to 1 within the plume boundary, has an average value of, typically, 1 in 5, or 0.2. That is, of all the individuals within the plume, only about 20 percent would be fatalities, assuming the population were evenly distributed.

Putting all this together, we can calculate the probability of an individual's fatality, P_I, as follows:

$$P_I = P_A \times P_T \times P_W \times P_P \times P_L$$

$$= P_A \times 1.0 \times 0.06 \times 0.3 \times 0.2$$

$$= P_A \times 0.004$$

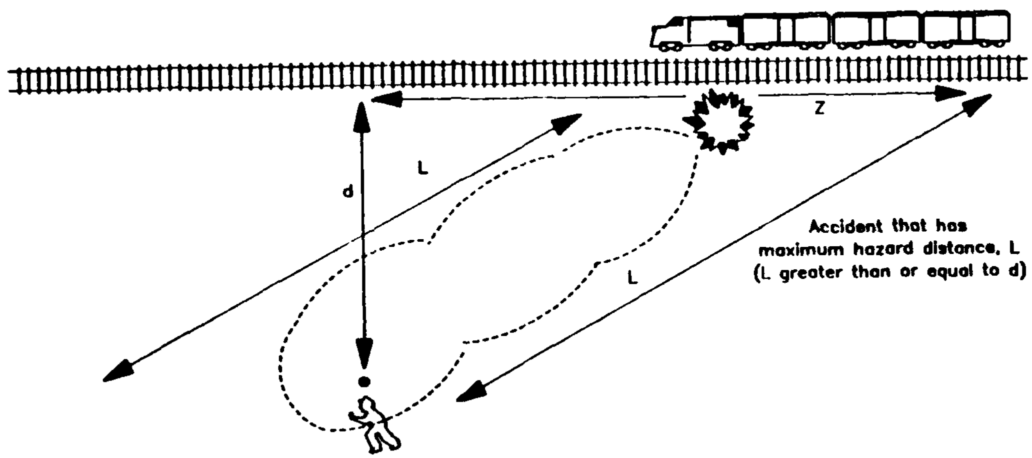
$$= P_A/250$$

This says that even if an accidental release does occur close enough to potentially harm an individual, the probability of the individual's death is about 1/250th of the probability (P_A) that the accident will occur there in the first place, which is itself an extremely small number. This, then, is the general method by which risk to the individual has been calculated. These factors are accounted for in the estimation of individual risk as reported in this analysis.

A.2.2 Computation of Individual Risk Along a Transportation Route

Figure A-1 introduces the additional considerations required when dealing with risk to an individual along a rail route or other transportation corridor. The factors affecting individual risk are the same as those discussed in conjunction with Figure 3, but a slightly more complicated calculation is required to estimate the probability of the accident occurring in a region that could affect the individual (i.e., the probability factors, P_A and P_T discussed above). As shown in Figure A-1, if an individual is located a distance, d, away from the rail route, and an accident produces a plume with a "no-deaths" hazard distance of length L, the individual could be killed if the accident occurred anywhere over a distance equal to 2 x Z, centered at the individual's location along the route.

FIGURE A-1
RISK TO AN INDIVIDUAL ALONG RAIL–ROUTE



Risk to the individual, P_I, *from an accident that has a* 'no–deaths' hazard distance of L:

$$P_I = \left[\text{Probability, } P_Z\text{, of an accident within a distance, } 2 \times Z\right] \times \left[\text{Probability of a lethal exposure to the resulting plume (see Fig. 4)}\right]$$

where:

$$P_Z = 2 \times \left[\text{Probability, } P_A^{(t)}\text{, of an accident per unit time, per train}\right] \times \left[\text{Time, t, required to travel a distance, Z}\right] \times \left[\text{Number, N, of trains passing this location}\right]$$

$$= 2 \times \left[\text{Probability, } p_A^{(t)}\text{, of an accident per unit distance, per train}\right] \times \left[\text{Distance, Z, over which a plume of length, L, could affect the individual}\right] \times \left[\text{Number, N, of trains passing this location}\right]$$

- **Estimation of risk due to that accident takes into account the occurrence anywhere within track length, 2 x Z**
- **Total individual risk is the sum of risks due to all accidents that can result in *hazard distances greater* than individual's distance from track**

To calculate the probability that an accident will occur within the relevant track segment, $2 \times Z$, (P_Z), we must account for:

- the probability, $p_A(t)$, of an accident per unit time (e.g., per hour) per train;
- the time, t, required for the train to traverse the track segment at $2 \times Z$;
- the number, N, of trains passing a given location.

Then:

$$P_Z = 2 \times p_A(t) \times t \times N.$$

However, since actuarial data on transportation accidents is provided to MITRE in terms of the probability of an accident per unit distance per train, $p_A(z)$, this analysis employs an equivalent expression for P_Z:

$$P_Z = 2 \times p_A(z) \times Z \times N.$$

Thus, the individual risk along a transportation route can be expressed either in terms of exposure time, t, or a hazard distance, $2 \times Z$, along the track, both of which are related to the distance the individual is from the route and the size of the potential accident. Time and distance are related to one another through the simple kinematic relationship involving the average train speed, v, which states that:

$$t = (2 \times Z)/v$$

For computational purposes, this risk analysis computes individual risk on the basis of lengths of track over which an accident can occur. As seen from the above, this is equivalent to basing individual risk on exposure time. To compute individual risk on the basis of lengths of track over which an accident can occur, it is assumed that the accident, if it occurs, could happen anywhere along the transportation route with equal probability. This is not strictly correct, given the variability of conditions along a rail corridor, but the best that can be assumed given the available data and the broad scope of the risk analysis.

Whether along a transportation route or near a fixed site, the total risk to an individual is the sum of the individual risks posed by each identified accident scenario that could happen at the individual's location.

A.2.3 Risk to the Population (Societal Risk)

To estimate the risk to the general population that may be affected by the CSDP, the factors defining risk to an individual, discussed above in sections A.2.1 and A.2.2, must be applied to the total number of individuals at risk. That is, if we estimate the risk to an individual at a given distance from a potential accident site, then the population risk is merely the product of the risk per individual times the number of individuals located at that distance from the accident. This concept is illustrated by Figure 4 (in the main body of this report). The dotted arcs in the figure define hazard distance zones for a given distance range from the potential accident site. For example, the distance zones used in this analysis are the following:

0.0 - 0.1 km	> 2 - 5 km
>0.1 - 0.2 km	> 5 - 10 km
>0.2 - 0.5 km	> 10 - 20 km
>0.5 - 1.0 km	> 20 - 50 km
>1 - 2 km	> 50 - 100 km

Thus, an accident having a "no-deaths" plume length of 12 km, for instance, is assumed to affect everyone in the circle out to 20 km from the accident site. If an accident causes a plume that reaches into the 10 - 20 km population zone, then all those in the inner population rings, closer to the agent source, are at even more risk since the dosages become higher as one approaches the accident site. Similarly, within a given distance zone, individuals will be affected not only by those scenarios for which the plume just reaches their zone, but also those accidents of greater magnitude for which the plume reaches into the outer zones.

There are two approaches to estimating risk to the population:

1. Estimate risk to an individual, as a function of his distance from the potential accident site, for each accident that could occur at the site. The cumulative risk to the individual is then computed as the sum of the risks from all the considered accidents. This cumulative individual risk is then multiplied by the population at that distance zone, and the results are summed for all distance zones to get the total population risk at a given site or locale. The result, in this case, is population risk expressed as total "expected fatalities," (typically, a number much less than 1). In this form, population risk accounts for both potential fatalities per event and the probability of that event occurrings.

2. Compute risk to the population for each accident by overlaying the lethal plume on the population about the site and estimating the number of potential fatalities within the plume. Expected fatalities is then computed as the product of potential fatalities and the probability of the accident occurring. The total

population risk is then determined by summing expected potential fatalities for all applicable accidents. This approach does not yield an intermediate estimate of individual risk; if individual risk is desired, it must be calculated separately.

In this risk analysis, a combination of the two approaches was used. Risk to the individual was calculated in a manner outlined in sections A.2.1 and A.2.2. Risk to the population was based on fatality estimates for a given accident magnitude at a given site, provided by Oak Ridge National Laboratory. The approach is detailed in Appendix B.

A.3 Accident Scenario Identification and Description

Accident scenarios are described by the following:

- A unique identification code which defines:
  - operational activity, with the major categories:
    - on-site handling
    - on-site transportation
    - handling at facility
    - plant operations
    - off-site transportation
    - interim storage (associated with off-site transport)
    - long-term storage
  - munition type
  - agent type
  - release mode
    - outdoor spill or leak (leading to evaporation)
    - detonation (without fire)
    - fire alone
    - combinations of the above
    - emissions resulting from a complex series of events, including indoor spills or releases
- A brief textual description of each scenario
- Agent release and probability data

The accident scenario identification code is described and defined in Table A-1.

TABLE A-1

ACCIDENT SCENARIO IDENTIFICATION CODE

Scenario ID is of the form: **XXYZWQnnn**

where: **XX** - Activity Code **W** - Release Mode Code
Y - Munition Code **Q** - Special Code
Z - Agent Code **nnn** - Scenario Number (See App. C)

ACTIVITY CODE (XX) DEFINITION

AF/AL/AT: Air transportation (C5A)* -- in-Flight/Landing/Take-off
BF/BL/BT: Air transportation (C141)*
HA/HB: Handling associated with air modes (A & B)
HF: Handling at the disposal facility
HO: On-site handling away from the disposal facility
HR: Handling associated with rail mode
HS: Handling during long-term storage*
HW: Handling associated with water mode
WB: Water transportation, barge in inland waterways*
WC: Water transportation, LASH ship in coastal waterways*
WI: Water transportation, LASH ship in inland waterways*
WS: Water transportation, LASH ship on the open seas*
PO: Plant operations
RN: Rail transportation, National
RR: Rail transportation, Regional
SL: Long-term storage
SR/SA/SB/SW: Temporary storage associated with transportation by rail, air(mode A), air(mode B), water, respectively
VO/VR/VA/VB/VW: On-site transportation associated with on-site, rail, air(A/B), and water disposal alternatives

MUNITION CODE (Y) DEFINITION

B: Bombs
C: Cartridges (105mm)
D: Mortar Shells (4.2in)*
K: Bulk ("ton") containers
M Mines
P: Projectiles (155mm)
Q: Projectiles (8in)*
R: Rockets
S: Spray tanks
W: Wet-eye bombs*
A: All munitions

AGENT CODE (Z) DEFINITION

G: Agent GB ("Sarin")
H: Agents H, HT, HD ("Mustard")
V: Agent VX
A: All agents

RELEASE MODE CODE (W) DEFINITION

A: Detonation
C: Complex mode (incl. indoor releases affected by building systems) or a combination of simple modes
F: Fire (incomplete combustion)
S: Spill (leading to partial evaporation

SPECIAL CODE (Q) DEFINITION

W: Warehouse Storage
O: Open Storage
6/8/9: 60/80/89 ft. Igloo

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* Defined for the June '87 accident scenario data base.

The quantitative description of each accident scenario consists of two types of risk-related data: event probability data and agent release data.

- Agent release data includes the following:
  - agent type
  - release mode (see above)
  - release time (where relevant)
  - surface character for evaporative releases (i.e., porous or non-porous)
  - location of evaporative releases (indoor, outdoor)

  These data are provided explicitly in the study by GA Technologies (GA Technologies, 1986[d], 1986[e], 1986[f]) or are directly inferrable from the accident description. With few exceptions, agent release data are not site-dependent.

- Event probability data are based on the site-specific expectation that an event will occur per unit time, per mile, or per storage unit-year (e.g., per igloo year). Converting probability data to a per-munition-stockpile basis for a given site requires knowledge of the classified inventory for each site as well as data on other site-specific factors affecting safety and risk (e.g., on-site transportation miles and plant production rates for each munition type).

A.4 Integration of Risk-related Data

An overview of the approach used for assimilating the probability and consequence information is depicted in Figure A-2. The analysis methods, including key assumptions employed, are described in Appendix B. The ovals on the left edge of Figure A-2 represent the four major data inputs to the risk analysis:

- Probability data (from GA Technologies)
- Agent release data (from GA Technologies)
- Meteorological data (from ORNL)
- Fatality data (from ORNL)

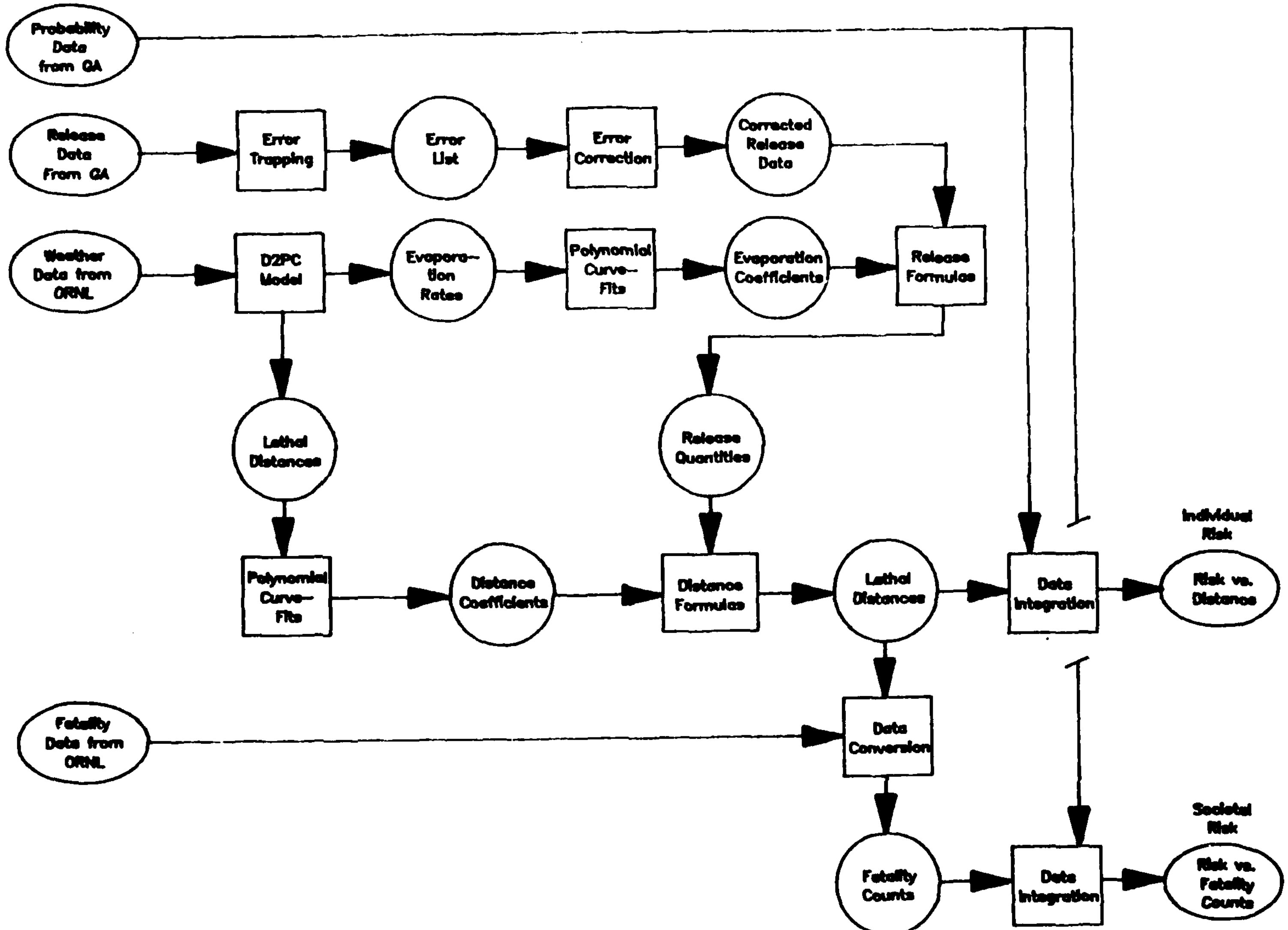


FIGURE A-2

SCHEMATIC DIAGRAM OF RISK DATA PROCESSING

These four major data sets are then integrated in ways that represent the disposal alternatives defined by the Army (OPMCM) to yield the two principal measures of risk (shown on the lower right of Figure A-2):

- o **Individual risk** (described by risk vs. distance from potential accident sites);

- o **Societal risk** (described by risk vs. potential fatalities per accident).

The probability data, expressed in terms of units appropriate to the particular activity type (e.g., events per train-mile or events per year of processing) need conversion in order that they relate to the entire munition stockpile at a specific site. The probability data, as provided by GA Technologies, are presented in both forms: as unit probability data and as converted to a per-stockpile basis for all of the disposal alternatives under consideration. As shown in Figure A-2, the probability data are combined with the consequence data (lethal distances and potential fatality estimates for each accident) to produce estimates for the two types of risk identified above.

The agent release data, as explained above, need to be related to potential fatalities. While other accident consequence parameters, such as agent quantity involved and size of the agent plume, are useful, they are not adequate for describing the impact. For instance, the same quantities of different agents lead to different plume sizes due to their varying physical properties, and same plume sizes of different agents lead to different impacts due to their varying chemical and toxic characteristics. Only the estimation of potential fatalities would account for all the different accident characteristics (e.g., agent type, release mode and time) and the meteorological and demographic characteristics of a particular site.

The key to linking agent release data with fatality data is the use of the Army's D2PC atmospheric dispersion model, the details of which are described in Appendix B.

Once the probability and consequence data for all accident scenarios at a particular site are assembled in a form that can be aggregated or further analyzed on a consistent and uniform basis, they can be fed into relative simple equations to estimate individual or population risks. More details of this process are discussed in the following section.

The societal (population-based) risk, for which consequence is expressed in terms of potential fatalities, is a measure that can be aggregated over the disposal sites and transportation routes as necessary in order to compare the total impact of each alternative. The comparison

of alternatives is aided by taking those alternatives in pairs and by site. In this manner, commonalities in hazards may be factored out, and the differences better understood.

Risk to the individual is strictly site-specific, and is dependent on the aggregate effect of the particular set of accidents that could happen at a given site for a specified disposal alternative.

A.4.1 Analysis of Event Probability

The procedure used tc analyze event probability data is illustrated in Figure A-3. Starting with the site-specific unit probability estimates prepared GA Technologies, probabilities were systematically computed in terms of events per munition stockpile for each site and each disposal alternative. The computations were performed on a series of spreadsheets permitting rapid recomputation whenever updated estimates of data affecting event probability are provided.

Site-specific stockpile-based probabilities were estimated by taking account of the following:

- o Munition stockpile data by munition type, agent type, and site;
- o Process throughput rates by munition type and facility type;
- o Military vehicle loadings for on-site transporation by munition type;
- o Munition storage configurations by munition type and site.

A.4.2 Analysis of Event Consequence

Consequence estimation involved four broad phases as described below.

A.4.2.1 Agent Release to Atmosphere. The analysis of agent release was the first step. For each identified event, the expected agent release was characterized by the following:

- o The amount of agent released to the environment;
- o The mode or modes by which the agent would be released to the atmosphere;
- o The time duration of the release.

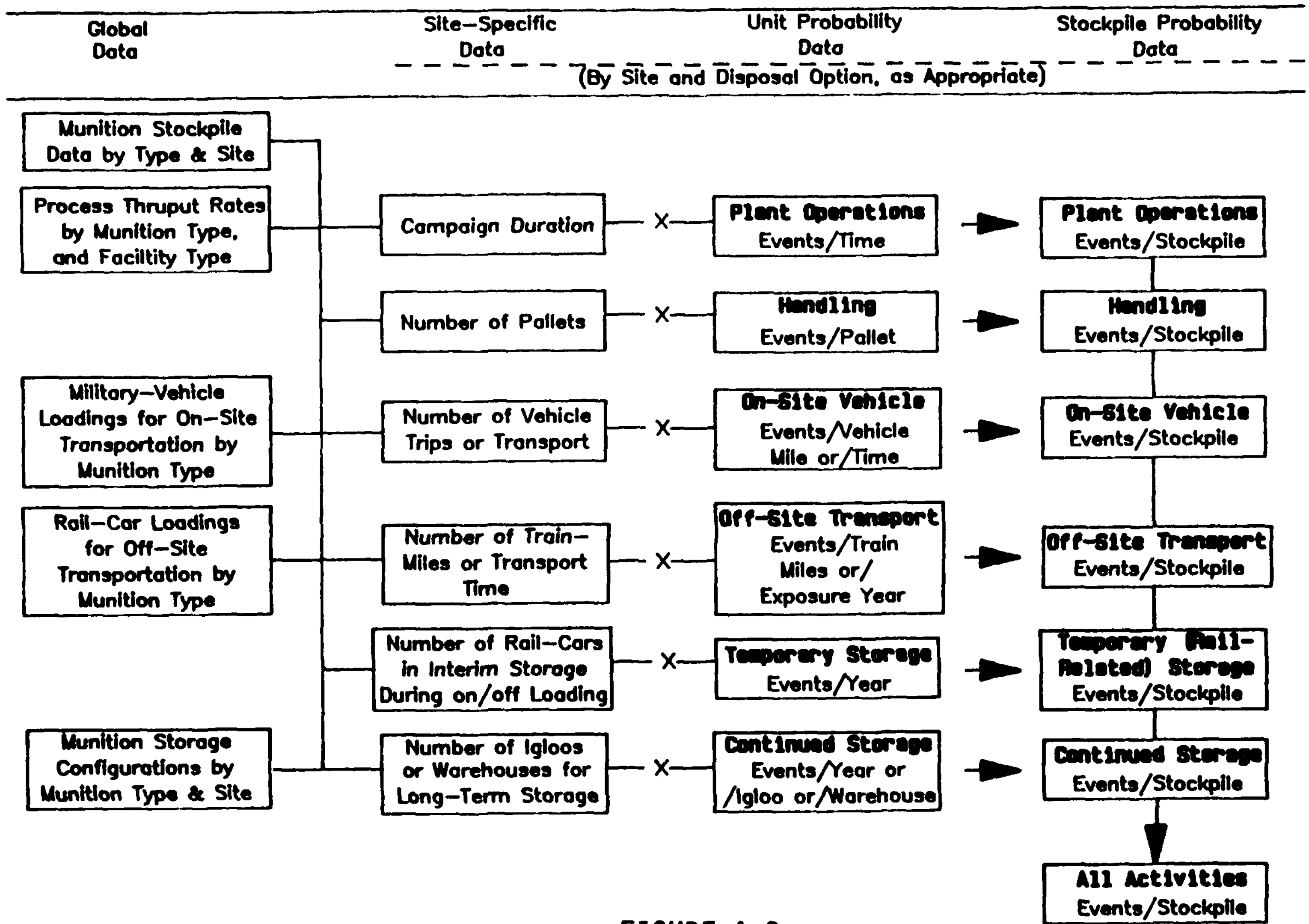


FIGURE A-3

ANALYSIS OF PROBABILITY DATA TO OBTAIN ACCIDENT PROBABILITIES FOR THE DISPOSAL OF THE ENTIRE MUNITION INVENTORY

The modes of release were grouped for calculation purposes into three categories. The Army's D2PC agent plume dispersion model can be used to calculate evaporation from a simple spill and can differentiate between a simple vapor release over a given period of time and an instantaneous release from a detonation alone. However, the D2PC model does not determine the amount of agent released during a fire, nor does it compute agent emissions involving a number of events in series such as agent emission through a plant ventilation system following an in-plant fire. Computation of downwind effects of combination releases must also be performed outside the model, using the results of the model as separately computed for each release mode. Therefore, the release data were provided for the model in three categories as follows:

1. A simple spill.

2. A release resulting from a detonation alone.

3. A combination or complex release involving an emission from a building or enclosure, a fire, or a combination of other release modes.

A.4.2.2 Toxic Plume Size. In the next step, toxic plume size was estimated for each event using the results of the Army D2PC model. Results were presented in a parametric form from which plume sizes could be obtained for the full spectrum of accident scenarios. The plume dispersion model predicts downwind distance to the 'no-deaths' dosage boundary for given meteorological conditions as a function of the following scenario-specific factors:

- Agent type

- Quantity released

- Release mode

- Event duration (the principal mechanisms for specifying emergency response capability at the accident site for a given event)

- Surface type (porous or non-porous)

- Spill area, if special conditions pertain to limit puddle size for spill releases

More details on the determination of plume size and representative lethal plume data are presented in Appendix B.

A.4.2.3 <u>Fatality Rate</u>. The third step in consequence estimation was the determination of the chance, based on statistical studies of agent toxicity, that the dose to an individual at a certain distance away from the source of the plume would result in fatality. This is a function of distance and expressed in terms of percentage fatality (e.g., zero percent, one percent, 50 percent). Also included in this determination is a factor to account for the chance of an individual being within the plume assuming that any wind direction was equally probable. (Refer to Appendix B.)

A.4.2.4 <u>Potential Fatalites</u>. The final step in consequence estimation was to relate each scenario to the potential number of fatalities that could result, given that the accident occurs. Potential fatalities per event is a function of the plume area (plume length times some effective plume width), the probability of a certain wind direction (assumed to be uniform for this analysis), the population distribution around each site, and the fatality rate obtained in the previous step. (Refer to Appendix B for more details.)

The data files of fatality estimates for given lethal plume lengths were prepared by the Oak Ridge National Laboratory as a major input to this risk analysis.

APPENDIX B

COMPUTATIONAL METHODS

APPENDIX B: COMPUTATIONAL METHODS

B.1 Introduction

This appendix describes the methods used by MITRE to convert the accidental agent release scenarios compiled by GA Technologies (GA Technologies, 1986[d], 1986[e], 1986[f]) into concise representations of total risk. First, the D2PC computer model was employed to determine each accident's potential to cause public fatalities. Next, the accident frequency estimates and fatality potentials were processed and combined in several different ways, in order to obtain quantitative indicators of risk. Finally, the error factors accompanying GA's accident frequency estimates were combined in order to delineate the uncertainties inherent in MITRE's results. This computational process is depicted in the form of a flow diagram as Figure B-1.

B.2 Use of the D2PC Model

B.2.1 Description of the Model

The U.S. Army's D2PC computer model is designed to analytically simulate the aerosolization, evaporation, transport, diffusion, deposition and inhalation of chemical agents. A schematic diagram showing the basic features of a general Gaussian diffusion model of which D2PC is representative is shown as Figure B-2. Although D2PC displays intermediate values obtained in the course of its computations, the ultimate output from any normal D2PC run is a distance. This is the distance directly downwind of an agent release to a point where a previously specified fatality rate or lethal "dose" is applicable. The D2PC standard fatality rates are 0 percent and 1 percent. Alternatively, a lethal "dose" is defined by specifying an equivalent exposure, expressed as a product of airborne agent concentration and exposure time.

B.2.2 Meteorological Conditions

General. Certain meteorological conditions were input to all of MITRE's MITRE's D2PC runs. All critical meteorological parameters were specified or approved by ORNL (in accordance with the Army's instructions to MITRE); the parameters are presented in Table B-1 and briefly described below.

The **mixing height**, which is an upper limit placed on the height above ground level to which agent is allowed to diffuse, was set at 750 meters.

The **Frost exponent**, which defines the power law relationship by which wind speed is assumed to vary with height above ground level, is used only for D2PC's vapor depletion calculations; it was set at 0.25. The **surface roughness** parameter was set at 1 centimeter. The latter two values were required in order to exercise D2PC's vapor depletion option.

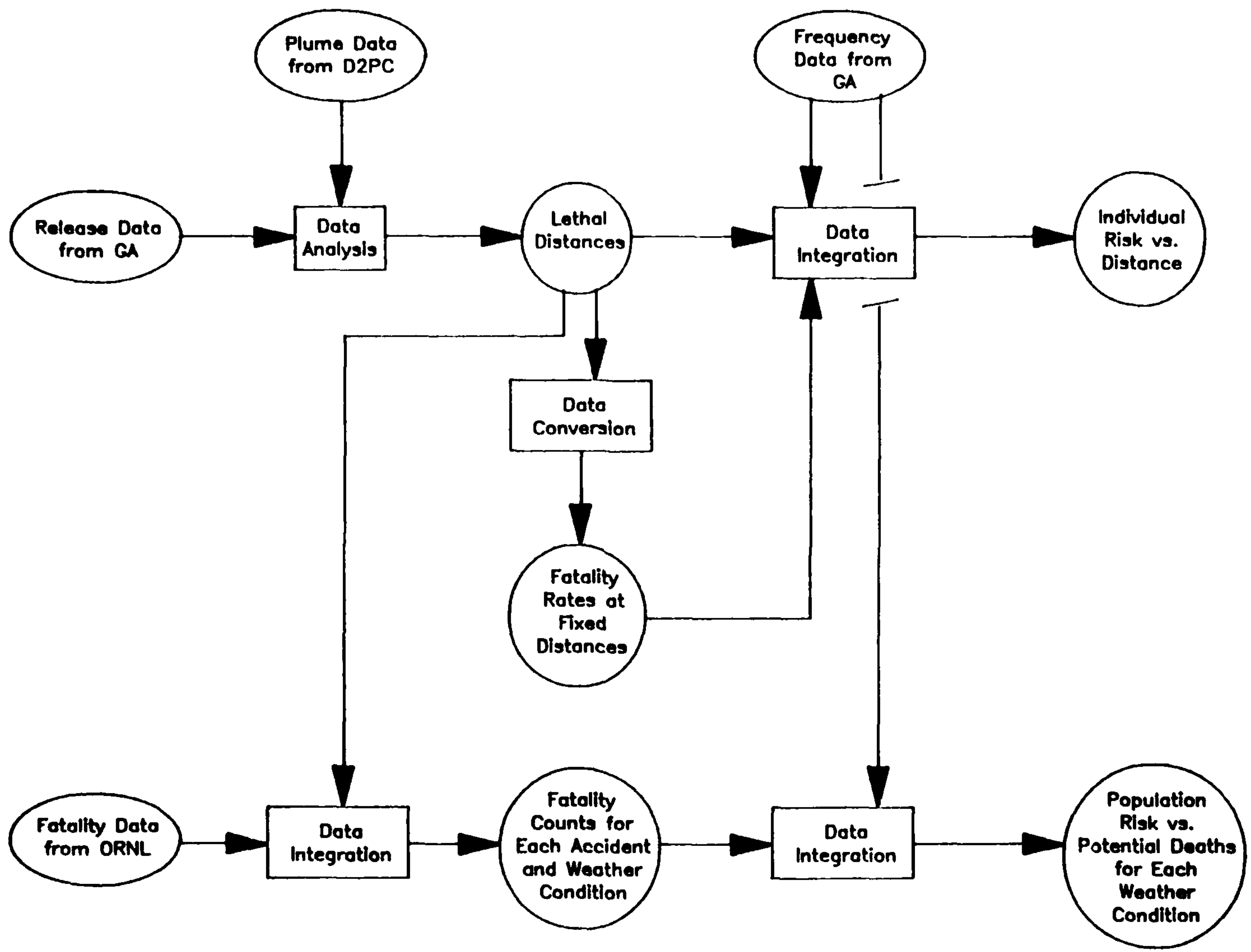
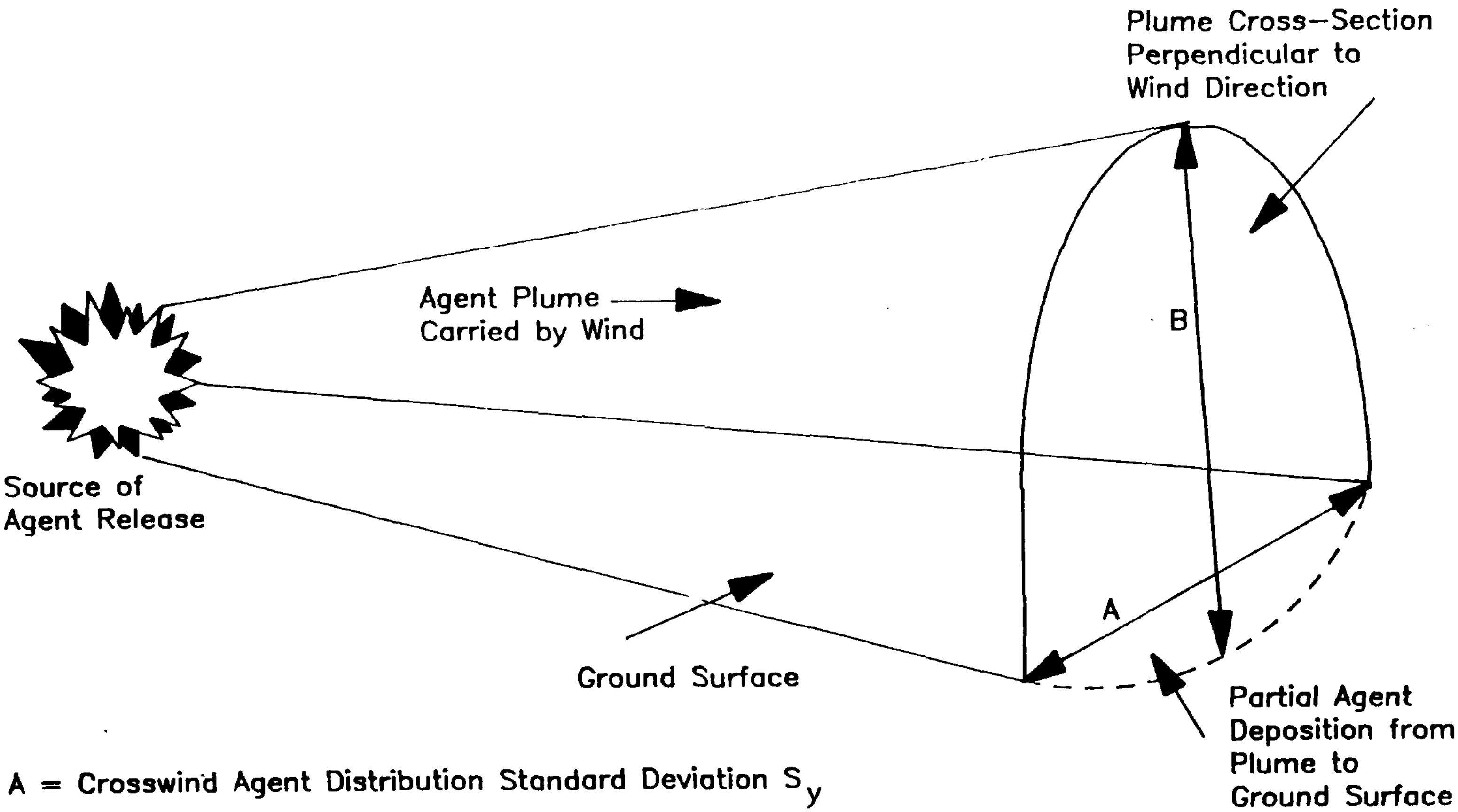


FIGURE B-1
SCHEMATIC DIAGRAM ILLUSTRATING RISK ESTIMATION



A = Crosswind Agent Distribution Standard Deviation S_y

B = Vertical Agent Distribution with Standard Deviation S_z

FIGURE B–2
SCHEMATIC DIAGRAM OF GAUSSIAN DIFFUSION
MODIFIED BY PARTIAL PLUME DEPOSITION ON GROUND SURFACE

TABLE B-1
SUMMARY OF INPUTS TO D2PC MODEL

Meteorological Condition	Worst Case	Most Likely (ML)
Atmospheric Stability Class	E	D
Wind Speed (Meters/Sec)	1	3
Temperature (°C)	30	20
Mixing Layer Height (Meters)	750	750
Vapor Depletion Code	1	1
Frost Exponent	0.25	0.25
Surface Roughness Parameter (Cm)	1	1
Release Code for Quantity Evaporated from Spill	EVP	EVP
Surface Code for Accident ID Initial Activity Letter:		
H, P, S[1]	NPR	NPR
A, B, R, S[2], V	GRA	GRA
W	No Evap.	No Evap.
Release Code for Agent GB Detonation (Including Combined GB Releases)	INS	INS
Munition Code (for Agent GB Yield from INS Release)	NON	NON
Release Code for All Other Cases	SEM	SEM
Release Time for SEM Releases[3] (Minutes)	2 (Minimum)	2 (Minimum)
	10	10
	60	60
	360 (Maximum)	360 (Maximum)
Exposure for 50% Fatality Rate (Mg-Min/M^3)		
Agent GB	70	70
Agent VX	30	30
Agent HD	1500	1500

[1]Except SL for munition-agent code KH at sites APG, PBA and TEAD.
[2]Only SL for munition-agent code KH at sites APG, PBA and TEAD.
[3]The listed value selected corresponds to the accident duration. For accident durations between two listed values, the lower listed value is selected. For releases whose durations exceed 1440 minutes, such as leaks from storage, D2PC is run using the actual release time and most likely conditions only.

All meteorological conditions, including wind direction, are constant within any D2PC run. In actuality, such conditions change. A change in wind direction can greatly reduce the maximum downwind (centerline) agent concentration at a specified distance. Therefore, although potentially lethal exposures were predicted to occur as far downwind as 900 kilometers during exploratory runs of D2PC, MITRE accepted an ORNL suggestion to consider potentially lethal effects only within the first 100 kilometers downwind of any release.

Most Likely Conditions. Most likely meteorological conditions were selected for use in obtaining best estimates of the expected public health impacts of accidental agent releases. These conditions are intended to represent non-site-specific averages which account for the full ranges of actual conditions.

The stability class describes the rate of eddy diffusion of agent released into the atmosphere. The D2PC model employs six modified Pasquill stability classes designated by the letters A through F. Class A corresponds to the highest diffusion rate, which occurs in a very unstable atmosphere (such as the type in which thermal convection leads to the rapid growth of thunderhead clouds). Class F corresponds to the lowest diffusion diffusion rate, which occurs in a very stable atmosphere (which is characterized by a strong inversion, which greatly inhibits the vertical rate of diffusion). For most likely conditions, stability class D (which is considered to be neutral--neither unstable nor stable) was selected.

The wind speed is also an important factor in calculating the evaporation (when applicable), transport and dispersion of agent releases. For most likely conditions, a low to moderate wind speed of 3 meters per second was selected.

The temperature is an important factor in D2PC's computations of evaporation rates. For most likely conditions, a non-site specific average outdoor temperature of 20 degrees Celsius was selected.

Worst Case Conditions. Worst case meteorological conditions were selected for use in obtaining upper bound estimates of public health impacts. A worst case stability class of E (a stable or inversion condition) was employed, since the extreme class F was judged (by ORNL) to be characterized by light meandering breezes such that the resulting downwind agent exposures would be only intermittent. A very low worst case wind speed of 1 meter per second was selected, as was a high worst case temperature of 30 degrees Celsius.

B.2.3 Evaporation of Spills

General. For many of GA's accidental agent release scenarios involving spills, and coded with a fifth letter of S (see Table A-1), the first

major step toward estimating public fatality potential was the determination of the portion of the quantity spilled that would be expected to evaporate. MITRE used the D2PC model's evaporative release mode to determine each spill's evaporation rate, which D2PC takes to be constant (until all agent is evaporated). MITRE then multiplied each evaporation rate by GA's accident duration (the time between the spill's occurrence and its cleanup or containment) in order to obtain the maximum quantity that could evaporate. The lesser of this quantity or the total quantity originally spilled was then used by MITRE as the amount of agent released into the atmosphere. In order to avoid repetitive runs of the D2PC model, 12 polynomial formulas for calculating evaporation rates (as functions of agent type, spill quantity, meteorological conditions, and surface types) were developed using multiple linear regression to determine the polynomial coefficients. The evaporation curves for the three agents are presented as Figures B-3 through B-5.

Surface Types. In the D2PC model, surface type is used to compute the surface area of a spill, which in turn is used to compute evaporation rates and maximum quantities. Spill scenarios associated with on-site truck and off-site air and rail transportation, as indicated by the initial identification letters V, A, and R, respectively, and only those storage accident scenarios indicated by the initial letters SL that include the agent code letter H (since mustard is stored outdoors at sites APG, PBA, and TEAD) were assumed to occur in unpaved areas best represented by D2PC's surface designation for "gravel". In D2PC, the term "gravel" refers to the uneveness of the surface that results in a spill of a relatively high average depth (about one-fourth of an inch), and of a correspondingly lower computed spill surface area and evaporation rate. Absorption of spilled agent by the surface is assumed not to occur.

All other spill scenarios requiring evaporation calculations were assumed to occur on paved areas, best represented by D2PC's "non-porous" surface designation. For spills on non-porous surfaces, D2PC uses a relatively small average depth (about one thirty-second of an inch) and therefore computes relatively high spill surface areas and evaporation rates.

B.2.4 Release Modes and Durations

General. In the D2PC model, the agent release mode may be specified as being evaporative (as described above), "instantaneous", or "semicontinuous". The instantaneous mode can be appropriate for certain cases (see below) involving the detonation of agent-containing munitions. For a specified type and quantity of chemical agent involved in a detonation, a D2PC run made for specific munitions types will give a different result than will a run made for "non-munition" detonations (i.e., detonations of unspecified munition types). The principal reason for this difference is that munition detonations are characterized by temperature-dependent yield factors. For example, according to the D2PC model, at ordinary ambient

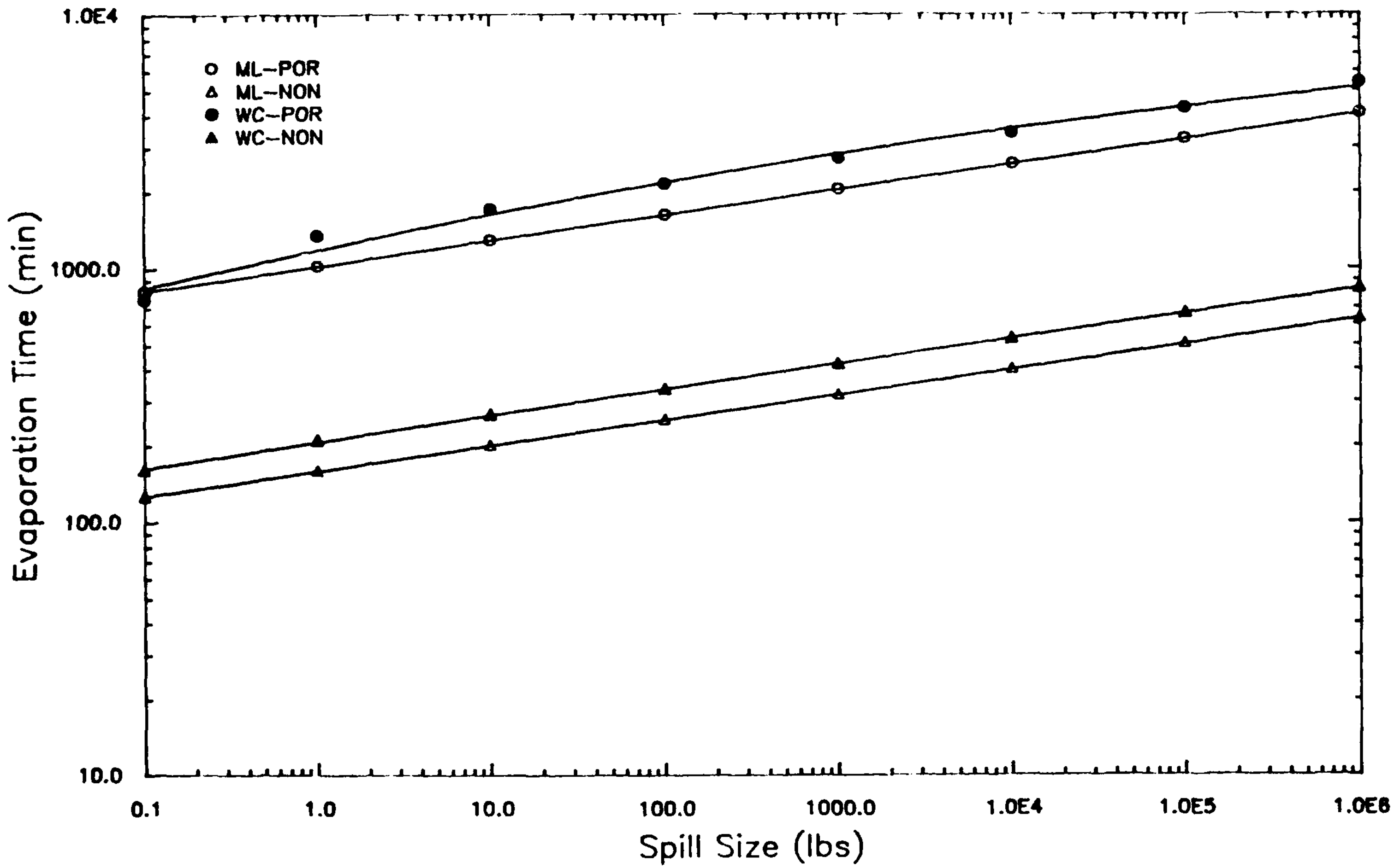


FIGURE B-3
EVAPORATION OF GB

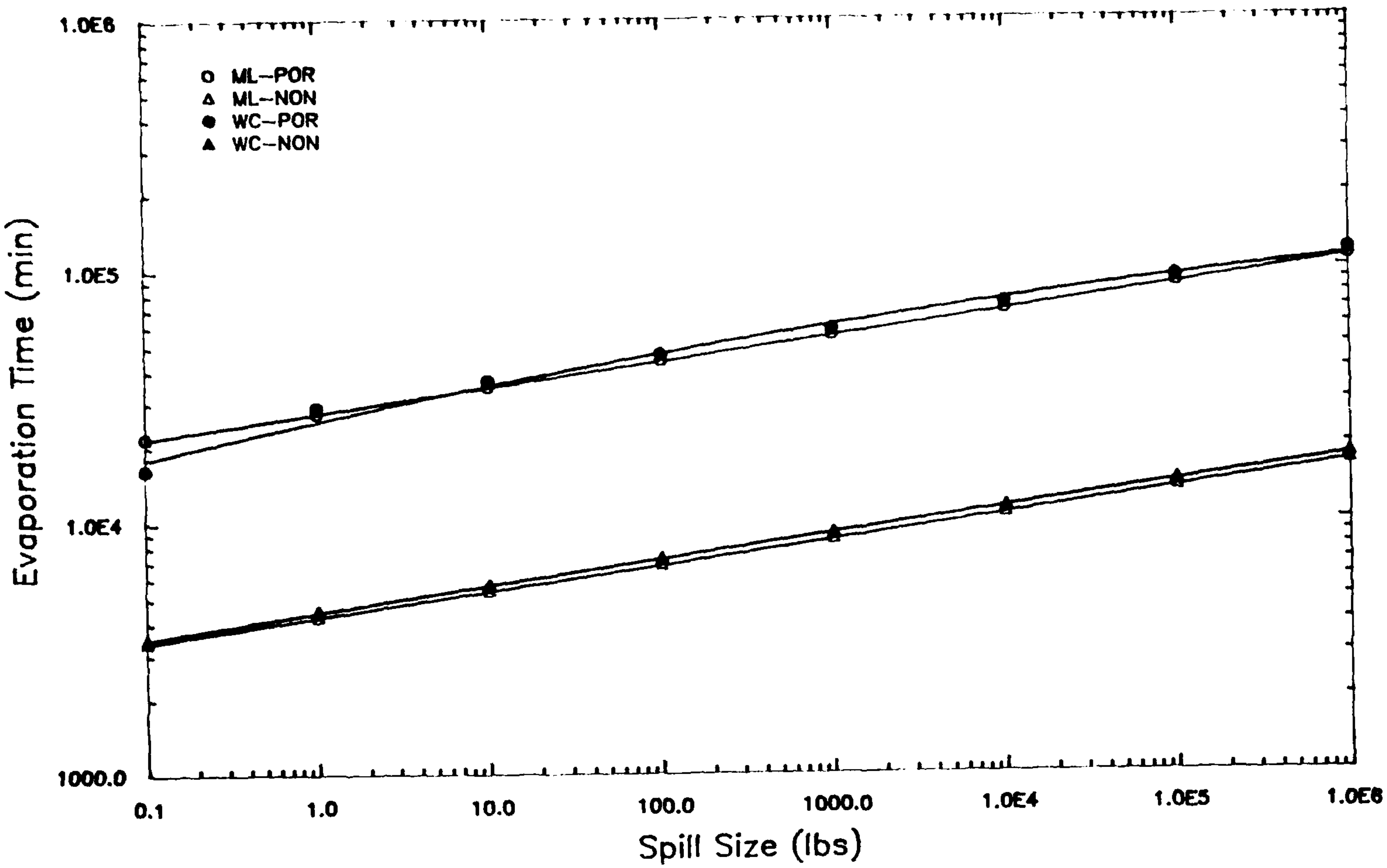


FIGURE B–4
EVAPORATION OF HD

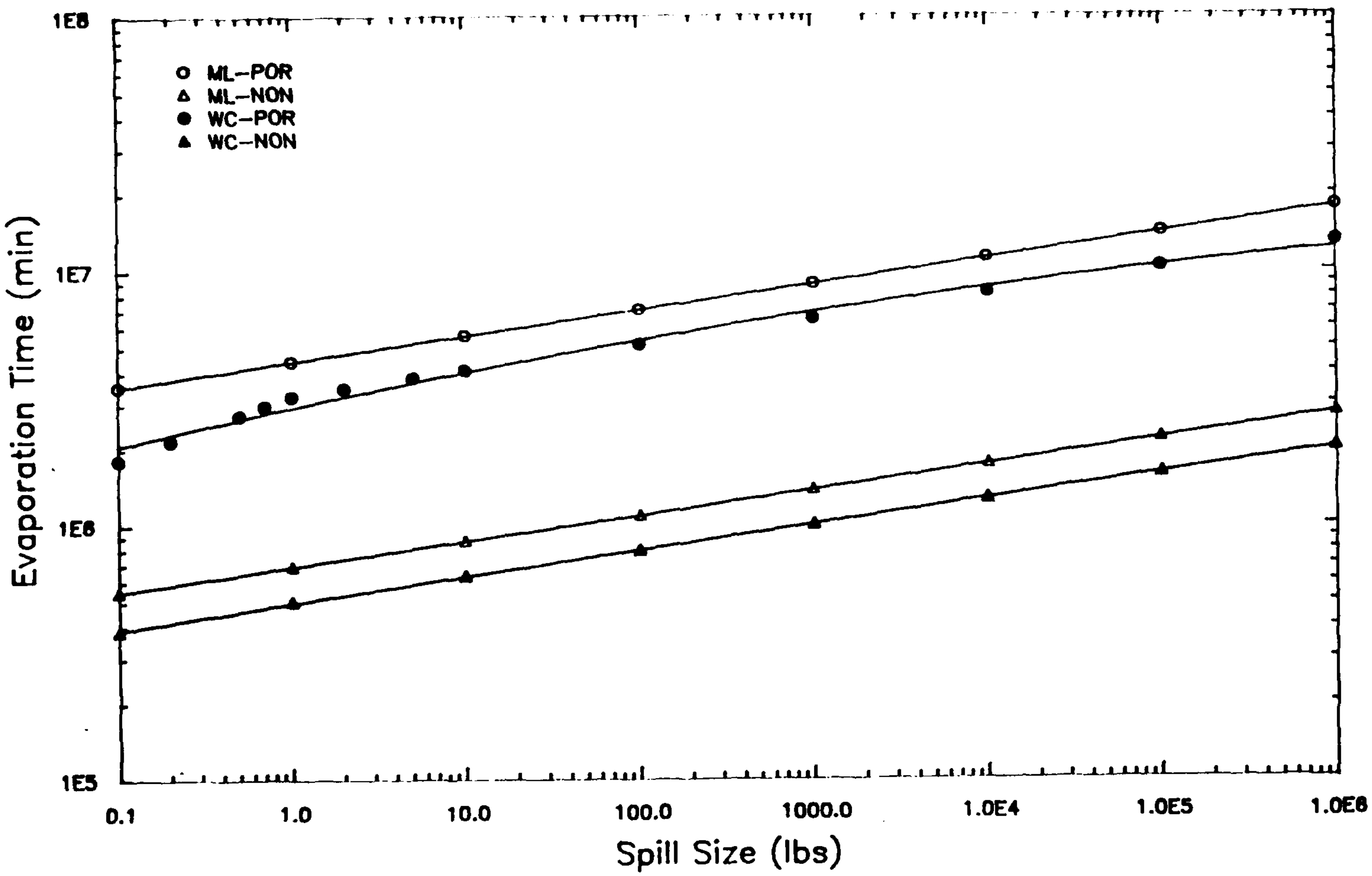


FIGURE B–5
EVAPORATION OF VX

temperatures, most munitions containing agent GB release about 75 percent of their agent contents to the atmosphere. However, at elevated temperatures, the yields increase to 100 percent. Since the predominant potential cause of accidental detonations inherent in the GA Technologies accident scenarios is the exposure of explosive munitions to fire and heat, in which case the yield should be 100 percent, MITRE ran its D2PC analysis of detonations by specifying non-munitions in all instances.

For all other (semicontinuous) releases to be evaluated using the D2PC model, both the release quantity and the release duration must be specified (though the duration does not affect the results in the case of agent HD). Both of these characteristics were listed for each accident scenario by GA Technologies. However, in order to avoid repetitive runs of the D2PC model, the standard durations used by MITRE were limited to the four values of 2 minutes (the minimum value that is appropriate for the model), 10 minutes, 60 minutes and 360 minutes. Where GA had listed an intermediate duration, the next smaller of the four values (but never less than 2 minutes) was used by MITRE. This results in a minor overprediction of dose acuteness and, therefore, of fatality potential. For releases whose durations exceeded 1440 minutes (such as leaks from storage), D2PC was run using the actual release times and most likely conditions only, because worst-case conditions and persistent wind direction were considered to be inconsistent with a duration exceeding 1440 minutes.

Agent GB. For accident scenarios involving the release of agent GB, as designated by a fourth identification code letter of G, the D2PC model was run either in its instantaneous release mode (for munition detonations, indicated by a fifth identification code letter of A, and by a duration of zero), or in its semicontinuous release mode (for all other release types). For GB release scenarios involving both detonations and semicontinuous releases (each of which would have been assigned a fifth identification code letter of C), the D2PC model was run as if the total of the two quantities were released instantaneously. This results in a minor overprediction of dose acuteness and fatality potential.

Agent HD. Agent HD was used to represent agents H, HT (a more dilute form), and agent HD (the distilled form) itself. Since agent HD is slightly more toxic than agents H and HT, this results in a minor overprediction of fatality potential. A greater overprediction results in cases involving spills (without fire) of HT, which is much less volatile than H and HD, and would evaporate so slowly as to pose little if any risk downwind. This overprediction may be of some significance for spills from ton containers at PBA, or from 4.2-inch mortar rounds at TEAD, both of which are filled with agent HT. However, spills of any of these low-volatility agents (H, HD or HT) pose little risk in any case.

Exploratory runs of the D2PC model indicated that, for a specified HD release quantity, the effects of an instantaneous release are much less

than those of a semicontinuous release. The reason for this is that instantaneous HD releases are taken in D2PC to be droplets, which impact mostly on the skin where the effects are relatively minor. Semicontinuous HD releases are taken to be vapors, which are inhaled into the lungs where the effects are much greater.

Recognizing that the D2PC model's algorithms for agent HD detonation were based on effects seen at small downwind distances, MITRE utilized the D2PC model's evaporation routine to determine whether the droplets emitted from a detonation would evaporate, and thus increase in effective toxicity, during their transport to distant receptors. MITRE performed this work by assuming that the maximum path length of air across a droplet (as opposed to the path length across the diameter of a circular spill, as used in the D2PC model) is one-half of the droplet's circumference. The results of this analysis, shown as **Figure B-6**, indicate that most if not all of the agent HD droplets could be expected to evaporate within a downwind distance of 3 meters per second (the most likely wind speed) times 300 seconds (the evaporation time for a droplet of 100 micrometer initial diameter -- see Figure B-6), or 0.9 kilometers. Therefore, with the concurrence of ORNL, MITRE elected to evaluate all accident scenarios involving agent code letter H by running the D2PC model in its semicontinuous mode (even for detonations, using the minimum allowable release duration of 2 minutes).

Agent VX. Exploratory runs of the D2PC model indicated that, for a specified VX release quantity, the toxic effects of an instantaneous release are less than or approximately equal to those of a semicontinuous release. As described above (with respect to agent HD), MITRE determined that, to a large extent, the instantaneously released aerosol (D2PC is based on an initial VX release of 87 percent aerosol and 13 percent vapor) would evaporate during its transport. For example, for an initial droplet diameter of 20 micrometers (droplets in the 50-100 micrometer size range are likely to fall to the ground within a few kilometers downwind and then evaporate), a 3 meter per second wind speed, and a downwind distance of 3 kilometers (corresponding to a 1,000 second transport time -- see **Figure B-6**), about 80 percent of the agent VX would be in the form of a vapor. Therefore, with the concurrence of ORNL, MITRE elected to evaluate all accident scenarios involving agent VX, as designated by a fourth identification code letter of V, by running the D2PC model in its semicontinuous mode (even for detonations, using the minimum allowable release duration of 2 minutes).

B.2.5 Lethal Exposures

General. As mentioned above, MITRE's approach to the quantification of public fatality potential was designed to minimize repetitive runs of the D2PC model. Therefore, through a limited number of model runs, MITRE was able to evaluate essentially all foreseeable accidental agent release scenarios, regardless of the number of identified scenarios. This was

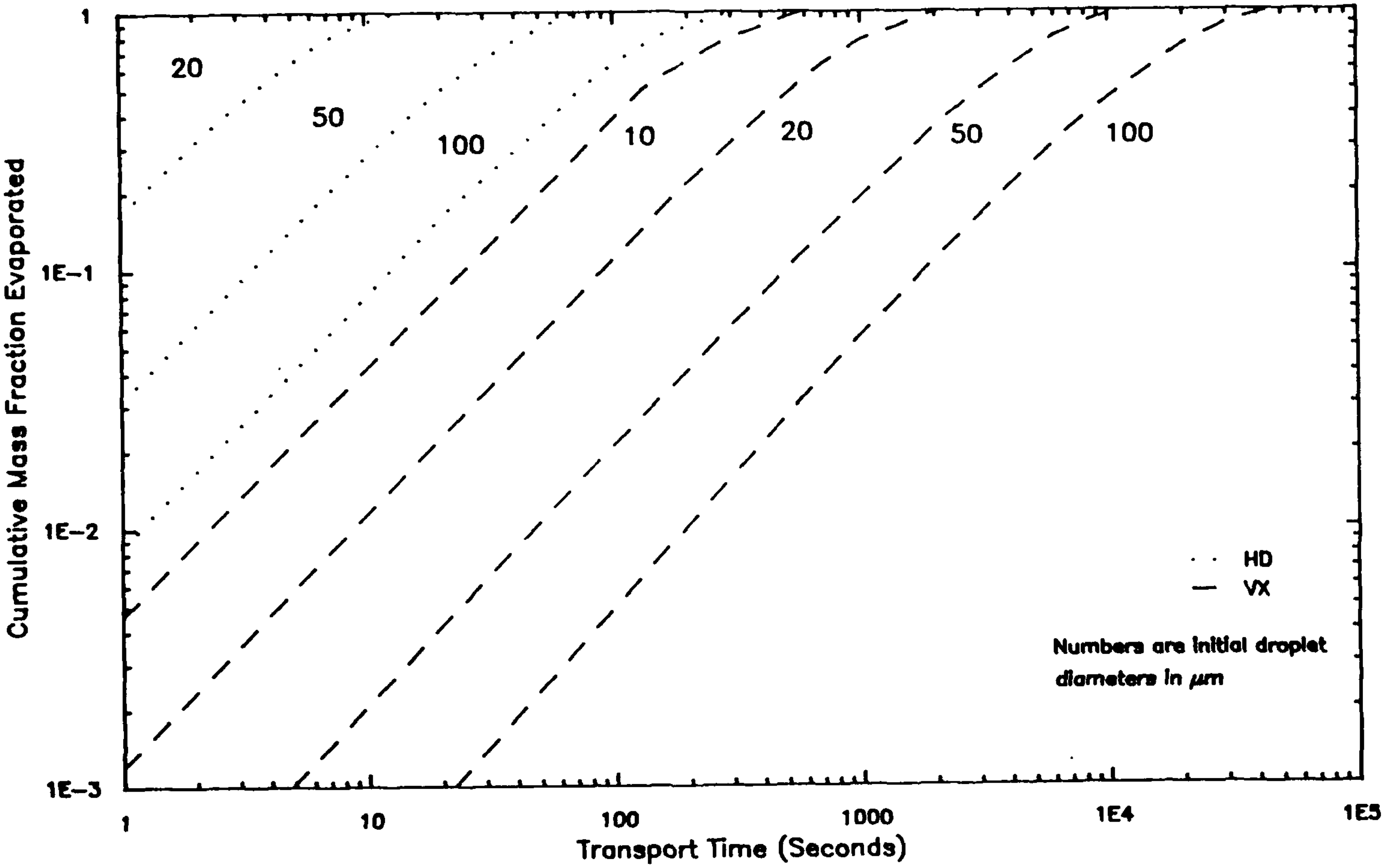


FIGURE B-6
AGENT HD & VX AEROSOL EVAPORATION
BASED ON D2PC MODEL

accomplished by developing 60 polynomial formulas, using multiple linear regression to determine their coefficients, for calculating distances to lethal concentrations as functions of agent type, release mode and duration, quantity released to the atmosphere, meteorological conditions, and fatality rate. Fatality rates of 0 percent and 1 percent are the standards incorporated into the D2PC code. (The agent doses used in the model are said to be based on the responses of healthy young men, rather than of more susceptible members of the public. Nevertheless, lacking acceptable alternatives, these data were used.) In order to define higher public fatality rates when applicable, MITRE also developed formulas for calculating distances to 50 percent fatality rates. The corresponding agent "doses" (actually, exposures) are presented in **Table B-1**. The graphical portrayal of the polynomial representations (curve-fits) for hazard distance as functions of release quantity are presented as **Figures B-8 through B-23** at the end of this appendix.

B.3 Quantification of Risk

On the basis of accident scenario probabilities and the potentially lethal effects of agent releases as characterized using the D2PC model, the risk inherent in the disposal program alternatives was quantified. The parameters used to quantify risk include potentially lethal distances, potential fatality counts, and various probabilistic values, as described below.

B.3.1 Potentially Lethal Distances

As described above, for each accidental agent release scenario, MITRE estimated the maximum downwind distance to locations where potential fatality rates of 0 percent, 1 percent and 50 percent would be applicable. (The use of the term "potential" refers to the lack of quantification of the preservation of lives that would result from preplanned emergency response measures that would be implemented by the U.S. Army and cooperating agencies. For example, no credit was taken for evacuation, or even for the protection afforded by remaining indoors.) MITRE estimated these distances for both the most likely and the worst case meteorological conditions. However, for the specific purpose of indicating the maximum distance from a release at which an agent fatality may result, MITRE selected only the greatest of the distances, the one corresponding to 0 percent fatalities under worst case meteorological conditions. As explained above, in each case the distance was limited to a maximum of 100 kilometers (per ORNL).

B.3.2 Individual Risk

General. In order to represent the risk to an individual, in terms of the probability of the individual's death due to an accidental release of agent, MITRE multiplied the probability of each accident by the potential fatality rate applicable at the individual's downwind distance; by the

conditional probability of the individual being in the direction downwind of the release; and, for accidents involving the off-site transportation of agent, by the conditional probability of the individual being at the specified distance and direction from the point along the route where the accident occurs. Following these multiplications, MITRE added the resulting potential fatality probabilities so as to obtain aingle probability representing the total risk at each distance con considered (see below). The procedures described here were performed based on most likely weather conditions only, as representative of an average of the entire spectrum of possible conditions.

Potential Fatality Rates. As explained above, the D2PC model computes downwind hazard distances as functions of specified fatality rates. However, in order to facilitate the summation and comparison of individual risks, MITRE elected to convert the D2PC results into calculated potential fatality rates as functions of specified downwind hazard distances. The ten distances selected by MITRE were 0.1, 0.2, 0.5, 1.0, 2.0, 5.0, 10.0, 20.0, 50.0 and 100.0 kilometers. For each accident scenario and each downwind hazard distance, MITRE estimated the potential fatality rate by piecewise linear interpolation. For cases in which the downwind hazard distance exceeded the distance corresponding to a 0 percent fatality rate, the 0 percent rate was used for the former distance. For cases in which the downwind hazard distance was less than the distance corresponding to a 50 percent fatality rate, the linear interpolation was based on an additional assumption, viz., that a fatality rate of 100 percent was applicable to a downwind hazard distance of zero (per ORNL).

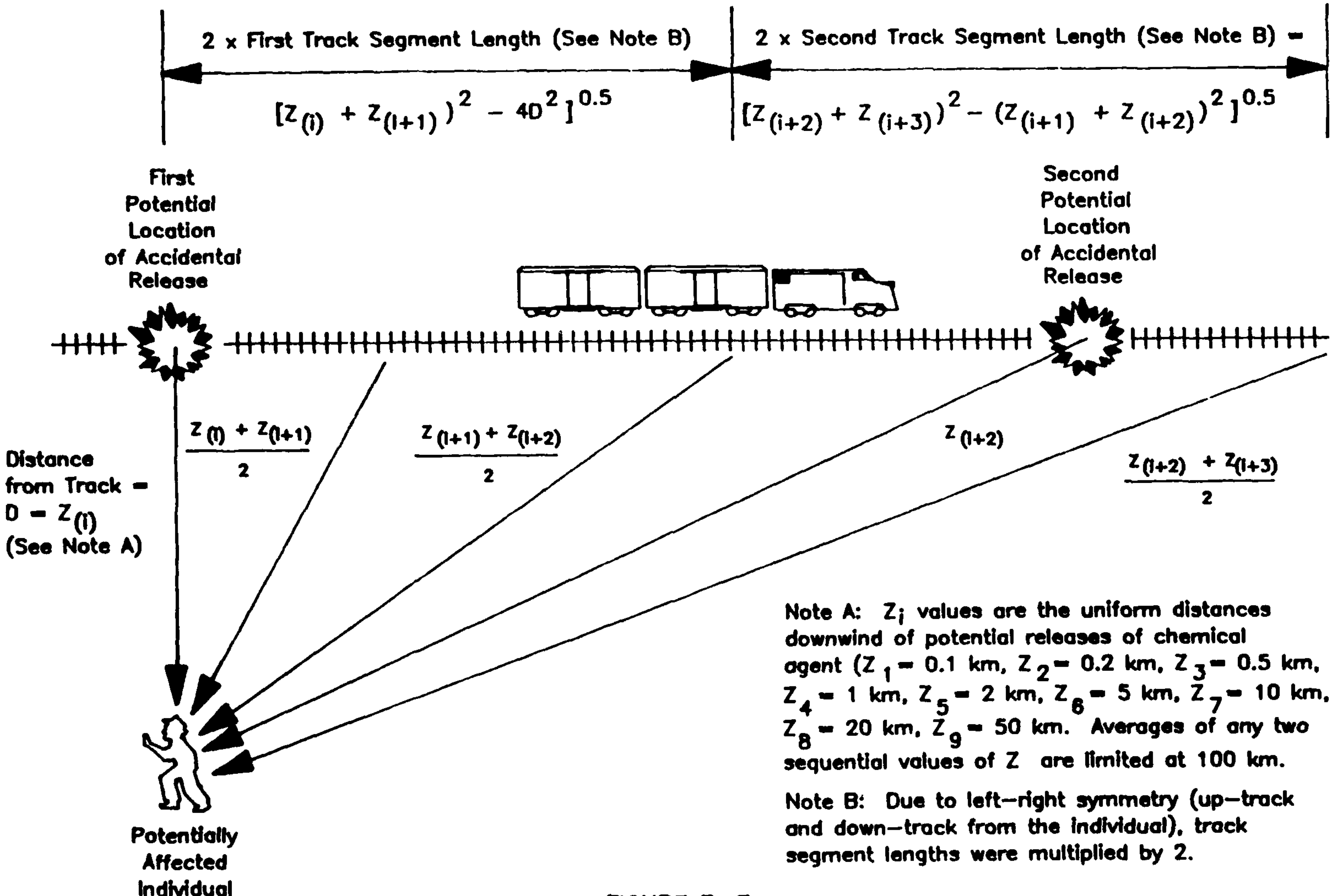
Width of Affected Area. The conditional probability of an individual being in the direction downwind of a release was calculated as the ratio of the agent "plume" width (which is actually an arc length) to the circumference of a full circle at the specified distance. Wind directional frequency weighting factors were not used (per ORNL guidance). Exploratory runs of the D2PC model, using an option with which plume widths are displayed as functions of downwind distance, indicated that plume widths can be approximated, with little loss of accuracy in estimating individual risks, as constant (square root of 2) multiples of the D2PC model's "sigma-Oy" function (indicated as "S_y" as Figure B-2). This power law function of distance defines a crosswind Gaussian distribution of agent concentration, and depends only on the stability class and the downwind distance. Under the most likely (stability class D) conditions, the sigma-y based plume width varies from 11.5 degrees of arc at 0.1 kilometers downwind, to 9.1 degrees at 1.0 kilometer, to 7.2 degrees at 10 kilometers, to 5.8 degrees at 100 kilometers. The general expression of the width in degrees is $9.13/(KM)^{0.1}$.

Time of Exposure to Off-site Transport Activities. In order to estimate the conditional probability of an individual being at a specified distance and direction from an off-site agent transportation accidental

release (assumed to occur at a fixed point rather than along a route segment), MITRE extended the individual risk methodology described above. In these cases, the individual risk is expressed as a function of the individual's perpendicular distance from the rail, air or water route, which was assumed to be straight. (Individuals on the inside of curved routes would experience somewhat greater risk; those outside of curved routes would experience less risk.) The model used for this portion of the analysis is illustrated as Figure B-7. The downwind distance range of the individual from the accident (not from the route) was assumed to be midway between the uniform distances specified above. For example, for the uniform distance of 10.0 kilometers, the downwind distance range was calculated as being from (5.0 km + 10.0 km)/2 to (10.0 km + 20.0 km)/2, or 7.5 kilometers to 15.0 kilometers. Next, the fractional times of exposure of individuals at each uniform distance from the route (not from the track) were assumed to be equal to the fractional distances of track involved. To continue the same example for an individual located 5.0 kilometers from the route, an accident 7.5 kilometers upwind would be $(7.5^2 - 5.0^2)^{0.5}$ km or 5.6 kilometers "up-route" or "down-route". An accident 15.0 kilometers upwind would be $(15.0^2 - 5.0^2)^{0.5}$ km or 14.1 kilometers up-route or down-route. Therefore, the length of the route over which the 10.0 kilometer potential fatality rate would be applicable to an individual 5.0 kilometers from the route would be (14.1 - 5.6) kilometers up-route plus (14.1 - 5.6) kilometers down-route, or 17.0 kilometers. The ratio of 17.0 kilometers to the total route length is assumed to be the same as the ratio of the individual's exposure time to the total travel time. This is the conditional probability by which the accident probability was multiplied in order to estimate the individual's risk. An exception to this general procedure was used whenever one of the uniform distances from the release exceeded the zero-fatality or no-deaths distance; since no risk is experienced at such distances, the entire exposure time within the non-deaths distance was attribute to the next lesser uniform distance.

B.3.3 Potential Fatality Counts

General. Potential fatality counts were computed by Oak Ridge National Laboratory as functions of accident location (any of the eight agent storage sites in the continental United States, and locations along the proposed 11 rail routes, two air routes, and one water route), lethal downwind distance (to the 0 percent fatality dose), and meteorological conditions. Therefore, MITRE employed its 0 percent fatality distances as obtained using the D2PC model in order to determine which of the ORNL fatality counts was applicable at any location. When MITRE's 0 percent fatality distances were intermediate between the uniform distance described above (which was used by ORNL as well as by MITRE), MITRE used the next higher uniform distance in order to select a fatality count. Since some of these 0 percent fatality distances were expected to exceed 100 kilometers, the standard distances were extended to include 200, 500 and 1,000 kilometers. However, although the releases resulting in these longer distances



Note A: Z_i values are the uniform distances downwind of potential releases of chemical agent (Z_1 = 0.1 km, Z_2 = 0.2 km, Z_3 = 0.5 km, Z_4 = 1 km, Z_5 = 2 km, Z_6 = 5 km, Z_7 = 10 km, Z_8 = 20 km, Z_9 = 50 km. Averages of any two sequential values of Z are limited at 100 km.

Note B: Due to left–right symmetry (up–track and down–track from the individual), track segment lengths were multiplied by 2.

FIGURE B–7

DETERMINATION OF TRACK SEGMENT LENGTHS CORRESPONDING TO DOWNWIND DISTANCES FROM POTENTIAL ACCIDENTAL RELEASES OF CHEMICAL AGENT

resulted in higher fatality rates within 100 kilometers, no fatalities occurring beyond 100 kilometers were counted by ORNL. Furthermore, in no case was a fatality count used that would correspond to a 0 percent fatality rate distance exceeding 1,000 kilometers.

Most Likely Weather. Only the ORNL fatality counts based on most likely meteorological conditions were used by MITRE to develop probabilities of fatal accidents, potential fatality expectation values, and risk curves (see below).

Worst Case Weather. The ORNL fatality counts based on worst case meteorological conditions were used only to estimate the upper limits of numbers of fatalities. These results provide one type of indication of risk.

B.3.4 Probability of a Potentially Fatal Accident

General. The probability of a potentially fatal accident was defined as the sum of the probabilities of all accidents having the potential to be fatal to one or more members of the public, based on most likely meteorological conditions. The methods used by MITRE to combine the probabilities of single potential fatality accidents result in minor overestimates. For example, if an accident is potentially fatal to no one 25 percent of the time it occurs, to one person 50 percent of the time, and to two people 25 percent of the time, then its (average) potential fatality count is 0 x 25% + 1 x 50% + 2 x 25%, or 1. MITRE would have treated the accident as always being potentially fatal. In actuality, only 75 percent of its occurrences are potentially fatal, and 25 percent are not.

Single Fatality Accidents. In order to calculate the probability of a potentially fatal accident, the probabilities of those accidents estimated to be potentially fatal to exactly one member of the public were added directly. More often, however, accidents had been estimated to be potentially fatal to some (average) number of persons that was fractional (between zero and one).

For example, an accident having a probability of 0.006 could have been estimated to expose 3 members of the public to agent at an average potential fatality rate of 1 percent. The initially calculated potential fatality count would have been 3 x 1%, or 0.03. Since an accident cannot result in fractional fatalities, MITRE interpreted the result as indicating that 0.03 or 3 percent of the occurrences of the accident would result in a single potential fatality. Therefore, for the purpose of estimating the probability of a potential fatality, MITRE redefined such accidents (those initially having fractional potential fatality counts) as single potential fatality events, and multiplied the initial probabilities by the initial fractional potential fatality count. In this example, the resulting

probability is 0.006 x 0.03, or 0.00018, for an equivalent potential fatality count of 1.

Multiple Fatality Accidents. MITRE added the probabilities of all multiple fatality accidents directly in order to estimate the probability of a potentially fatal accident. For this purpose, the definition of multiple fatality accidents includes those whose (average) calculated potential fatality counts were between 1 and 2 (that is, average fatality counts can be fractional, and any value greater than 1.0 -- such as 1.2 -- is considered "multiple"). Since such accidents would sometimes be expected to result in no potentially fatal exposures (though at other times to result in 3 or more), this method results in minor overestimates, as described above.

B.3.5 Potential Fatality Expectation Values

General. MITRE calculated potential fatality expectation values by multiplying the accident probabilities and their corresponding potential fatality counts, and summing these products. The result is an average or mean number of potential fatalities. For example, an accident with a probability of 0.01 and a potential fatality count of 1,000 would have a potential fatality expectation value of 0.01 x 1,000, or 10. However, this result of 10 is an average which results from a combination of the accident's unlikelihood and its severe consequences. The accident would probably not occur at all but, if it did occur, it would be expected to be potentially fatal to hundreds or thousands of people. In actuality, it might never be potentially fatal to exactly 10 people, but 10 is the average consequence (an average of many zeros, and a very few large numbers of potential fatalities). Nevertheless, the "equivalent" of 10 potential fatalities is a result which one may consider to be comprehensible.

Changing the example to one representing a safer program, an accident with a probability of one in a million, or 0.000001, and a potential fatality count of 5, has a potential fatality expectation value of 0.000001 x 5, or 0.000005. This result is equivalent to one two hundred thousandth (1/200,000) of a potential fatality. One may have difficulty in comprehending such a result. One way of doing so (not without its shortcomings) is to consider the result as "equivalent" to a shortening of a potentially affected individual's remaining life span, which may be estimated here as 40 years. The equivalent lifespan shortening potential of the accident would be calculated as 0.000005 x 40 years, or 0.002 years, or 18 hours of one person's life.

However, one may prefer to forego any use of "equivalents", and to regard potential fatality expectation values simply as statistics that combine probabilities and potential fatalities in order to facilitate the comparison of risks.

B.3.6 Risk Curves

General. In order to develop graphical representations, commonly referred to as risk curves, of the probabilities of exceeding specified potential fatality counts, MITRE began by adding the probabilities of all accidents exceeding each occurring potential fatality count for the most likely weather conditions. For this purpose, the initially calculated potential fatality counts that were fractions of one were increased to one, and the corresponding probabilities were multiplied by the initially calculated fraction, as described above. The resulting cumulative probabilities were then shown on the vertical logarithmic scale of a graph as single point functions of the potential fatality counts, shown on the graph's horizontal logarithmic scale. Sequences of points were connected by straight line segments, and the results were presented as risk curves. Since each potential fatality count that is exceeded is a lower limit of a range (e.g., a 7-kilometer lethal distance could result in a potential fatality count between 12 and 37, the ORNL counts for 5-kilometer and 10-kilometer lethal distances, respectively; the lower limit would be 12), and the logarithmic probability scale cannot be extended to zero (which has no finite logarithm), the uppermost count is not graphed, but is noted as the value not exceeded.

B.3.7 Treatment of Uncertainty

Uncertainties in risk estimation arise due to many causes, including the inadequacy of data, inaccuracies in modeling, and the incomplete identification and understanding of accident phenomena. This section discusses the basis for estimating uncertainties when summing probabilities or probability-weighted data with known individual uncertainties.

The analysis of accident scenarios carried out by GA Technologies provides an error factor for each accident probability "point estimate". Each error is an error of a median, not of a probability distribution, and does not include numerous unquantified and unquantifiable sources of error. Nevertheless, this error factor was used by MITRE to characterize the uncertainty inherent in each estimate. The contribution to risk uncertainty of consequence estimation (for example, in estimating potential public fatalities as a result of an agent release) is represented separately (though incompletely) by considering most likely and worst case meteorological conditions. However, since worst case conditions occur relatively rarely and have greater consequences, they may have little effect on a risk curve, which, by definition, is a monotonically decreasing function indicating lower probabilities for greater consequences.

The accident probability estimates provided by GA Technologies were assumed to be median values of lognormal distributions whose error factors or range factors are the ratios of the 95% confidence values to the corresponding median values. The error factors were used by MITRE to convert

all median risk estimates to their mean values. Within any single activity type (e.g., handling, plant operations, storage, or transport by a given mode), the error factors were conservatively assumed to be totally systematic (highly and positively correlated). Thus, the upper bounds of accident scenario probabilities (that is, the products of the point estimate probabilities and their corresponding error factors) were added directly in order to obtain the upper bounds of accident probabilities for entire activity categories. Error factors for entire categories were calculated by dividing these upper bound sums by their corresponding point estimate sums. These error factors were then used to obtain variances on the mean values. Subsequent arithmetic, for example, the addition or subtraction (for comparison of differences) of probabilities corresponding to different activity types (which were assumed to have totally independent [non-correlated] error factors), was performed by adding these variances (rather than by adding upper or lower bounds). Finally, the variances were converted back to error factors in order to define the probability-related uncertainties of the risk curves and the potential fatality expectation values.

The formulas used in the uncertainty computations are presented in Table B-2.

B.3.8 Probability of a Difference in Risk

In order to estimate the probability that the risk (in terms of expected fatalities, F) of any alternative i exceeds the risk of alternative j, the following test statistic (TS) was employed:

$$TS_{i-j} = \frac{LN(F_{i-j}) - LN(F_{j-i})}{(\sigma^2_{i-j} + \sigma^2_{j-i})^{0.5}}$$

$$= \frac{1.645 * LN(F_{i-j} / F_{j-i})}{(LN^2 EF_{i-j} + LN^2 EF_{j-i})^{0.5}}$$

where the subscripts, i-j and j-i, refer to the independent accident scenario data bases obtained by eliminating commonality (i.e., all accidents with identical probabilities under both alternatives and all portions of accident probabilities that are common to both alternatives).

TABLE B-2
UNCERTAINTY FORMULAS

(1) $P_{mean} = P_{med} \times EXP[(LN^2 EF)/5.412]$

where P_{mean} = mean probability of accident

P_{med} = median probability of accident

EF = error factor (of accident probability)

(2) $EF_{act} = \Sigma(P_{mean} \times EF)/\Sigma P_{mean}$

where EF_{act} = activity's error factor (of accident probability)

(3) $P_{act} = \sum_{act} P_{mean}$

where P_{act} = activity's probability of accident

(4) $V_{act} = (\Sigma^2 P_{act})[(EXP[(LN^2 EF_{act})/2.706])-1]$

where V_{act} = activity's variance (of accident probability)

(5) $V_{alt} = \Sigma V_{act}$

where V_{alt} = alternative's variance (of accident probability)

(6) $P_{alt} = \sum_{alt} P_{act}$

where P_{alt} = alternative's probability of accident

TABLE B-2 (Concluded)
UNCERTAINTY FORMULAS

(7) EF_{alt} $= EXP(LN^{0.5}[(V_{alt}/\Sigma^2 P_{alt})+1]^{2.706})$

where EF_{alt} = alternative's error factor (of accident probability)

(8) UB_{alt} $= P_{alt} \times EF_{alt}$

where UB_{alt} = alternative's upper bound (of accident probability)

(9) LB_{alt} $= P_{alt} \div EF_{alt}$

where LB_{alt} = alternative's upper bound (of accident probability)

Note: For expected fatality (instead of probability) uncertainty, substitute Pmed x Fatality Count for Pmed.

Then, the probabilities of excess risk (P_{i-j} and P_{j-i}) were calculated using the following relationships:

$$P_{si-sj} = s \times ERFF(TS_{i-j})$$

$$P_{sj-si} = 1 - [s \times ERFF(TS_{i-j})]$$

where s is the sign (plus or minus) of TS_{i-j}, and ERFF is the error function as computed by the Army's D2PC model using the Hastings approximation. Note that in D2PC, ERFF(0) = 0.5, ERFF(-1.645) = 0.05, and ERFF(1.645) = 0.95.

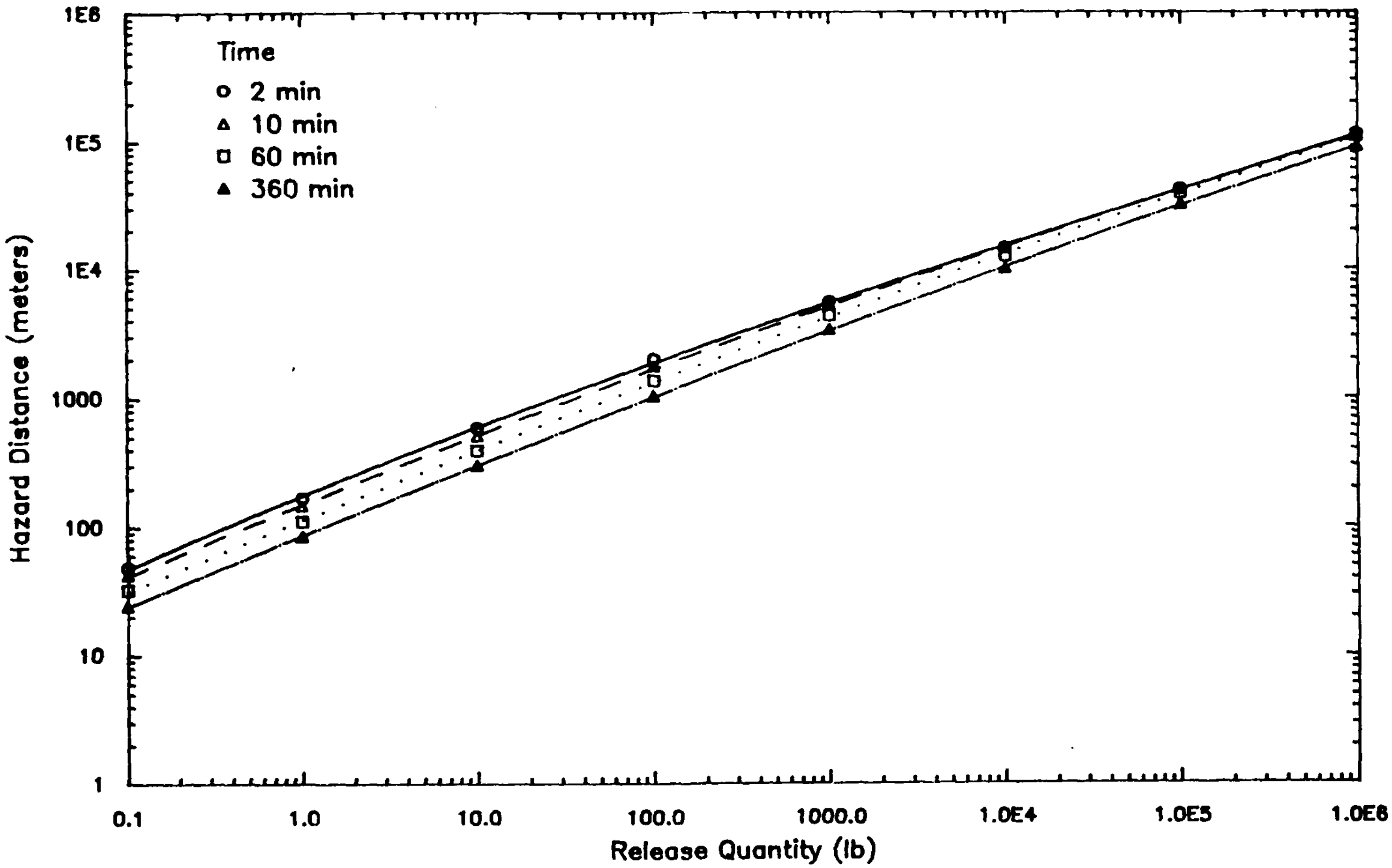


FIGURE B–8
HAZARD DISTANCES FOR GB
ML Weather, 0% Lethality
Semicontinuous Release Mode

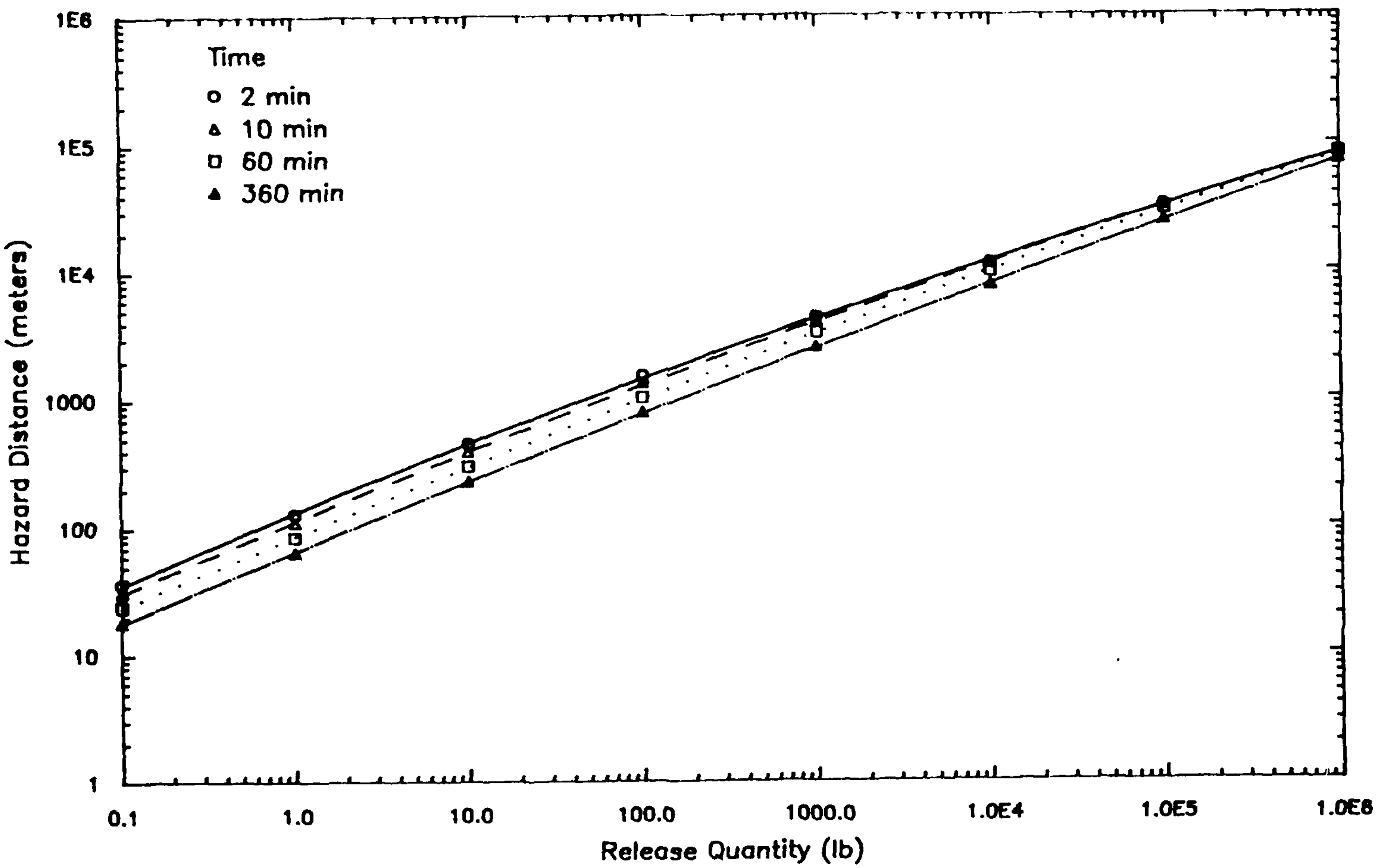


FIGURE B-9
HAZARD DISTANCES FOR GB
ML Weather, 1% Lethality
Semicontinuous Release Mode

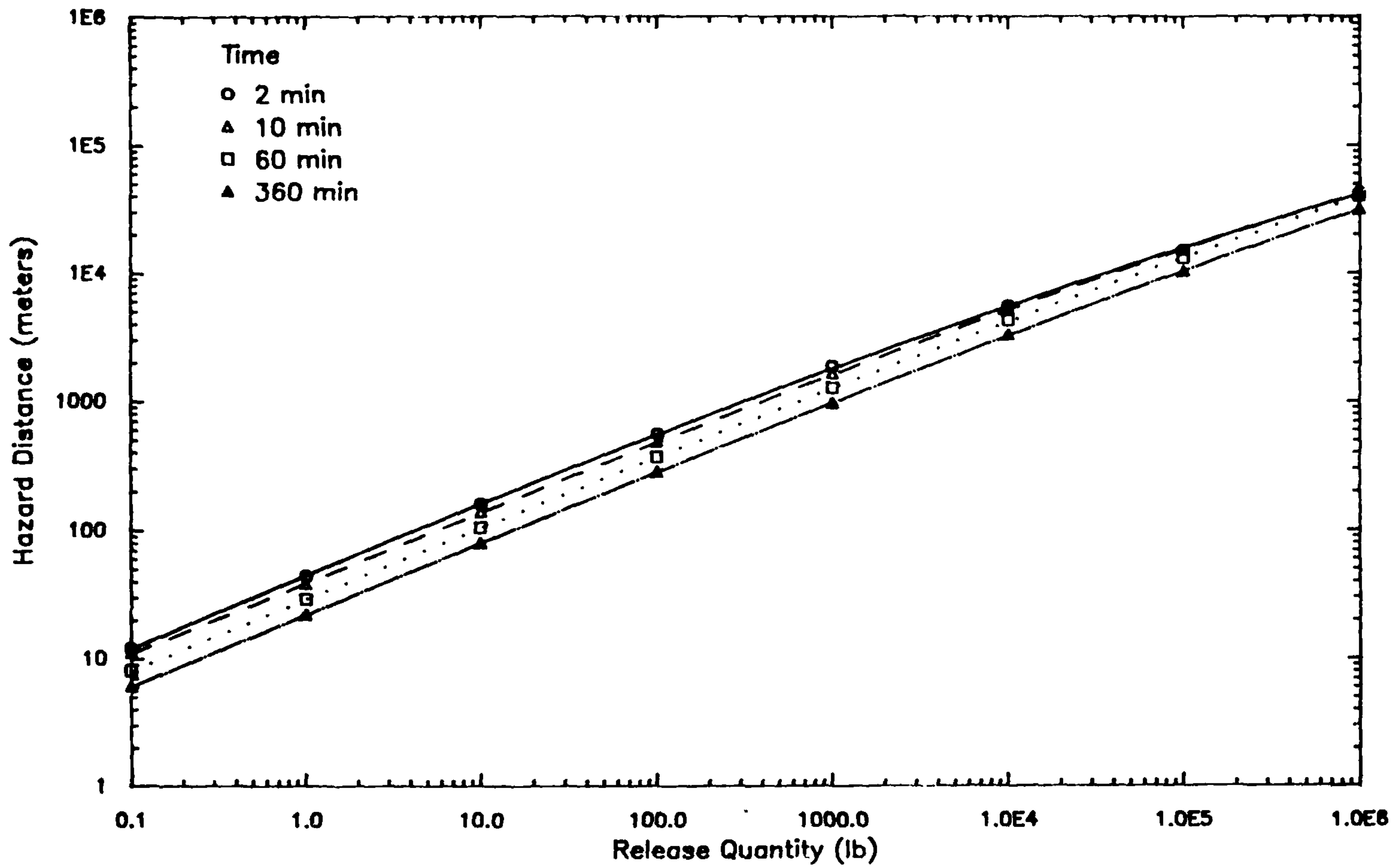


FIGURE B–10
HAZARD DISTANCES FOR GB
ML Weather, 50% Lethality
Semicontinous Release Mode

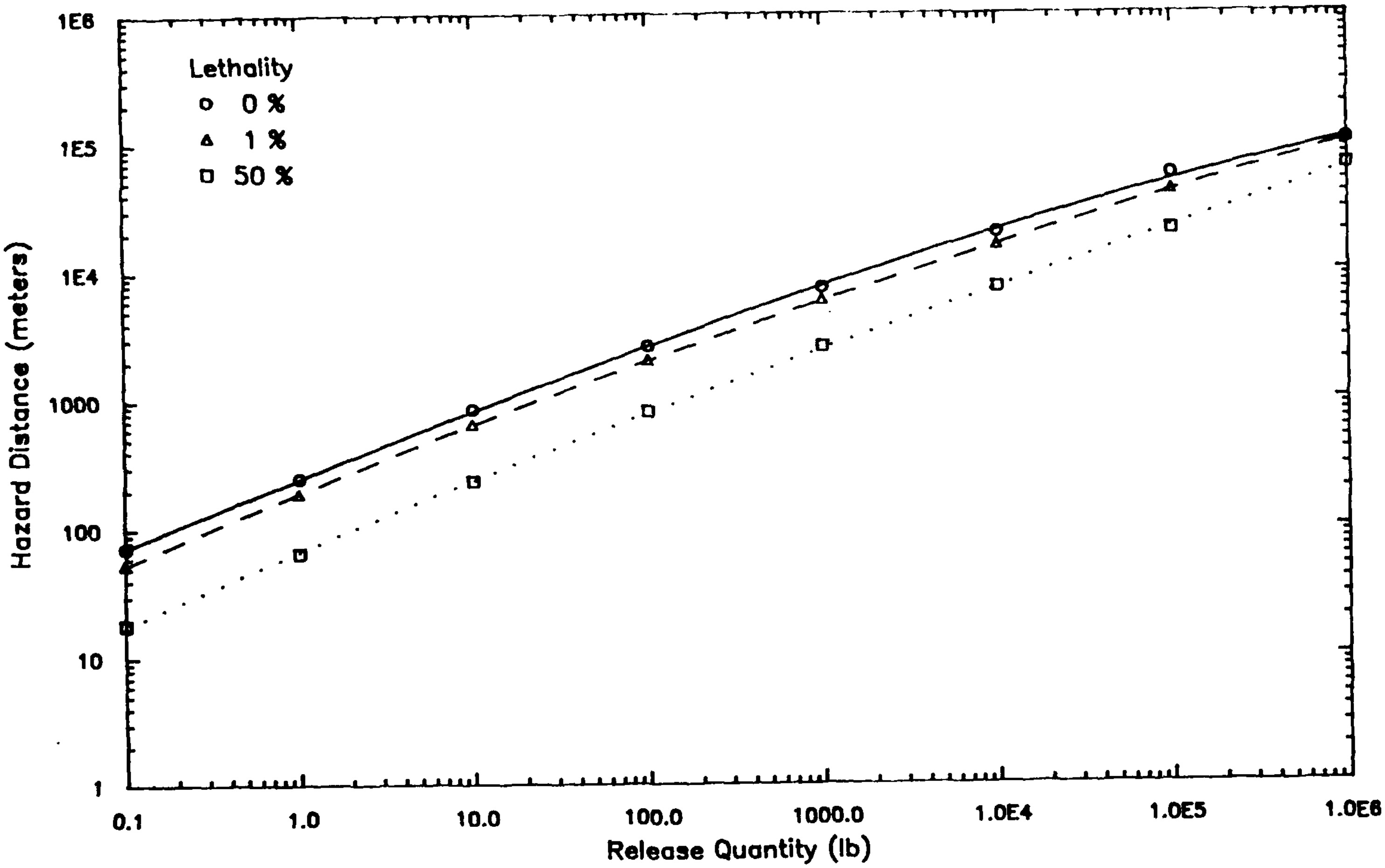


FIGURE B-11
HAZARD DISTANCES FOR GB
ML Weather, 0%, 1%, and 50% Lethality
Instantaneous Release Mode

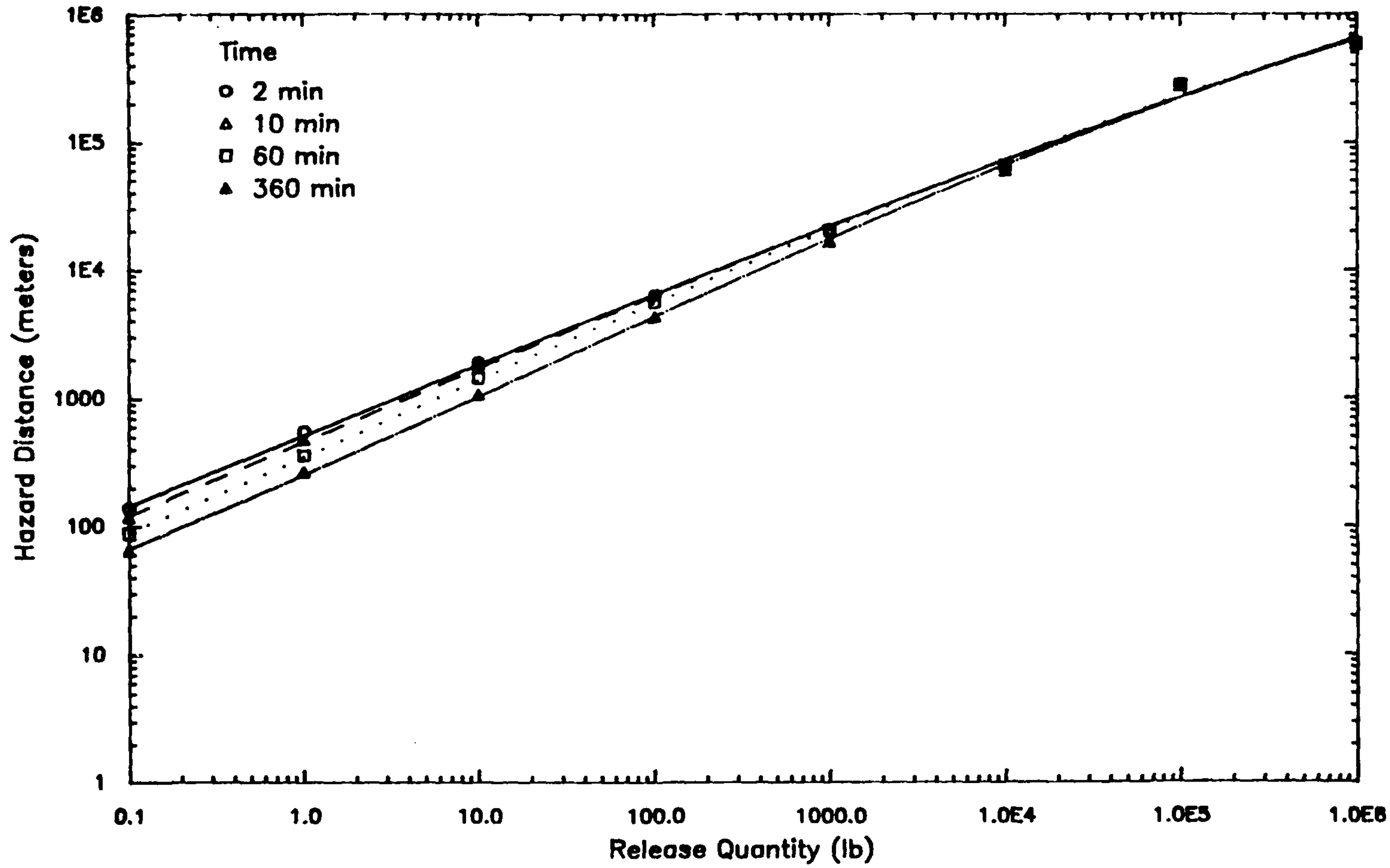


FIGURE B-12
HAZARD DISTANCES FOR GB
WC Weather, 0% Lethality
Semicontinuous Release Mode

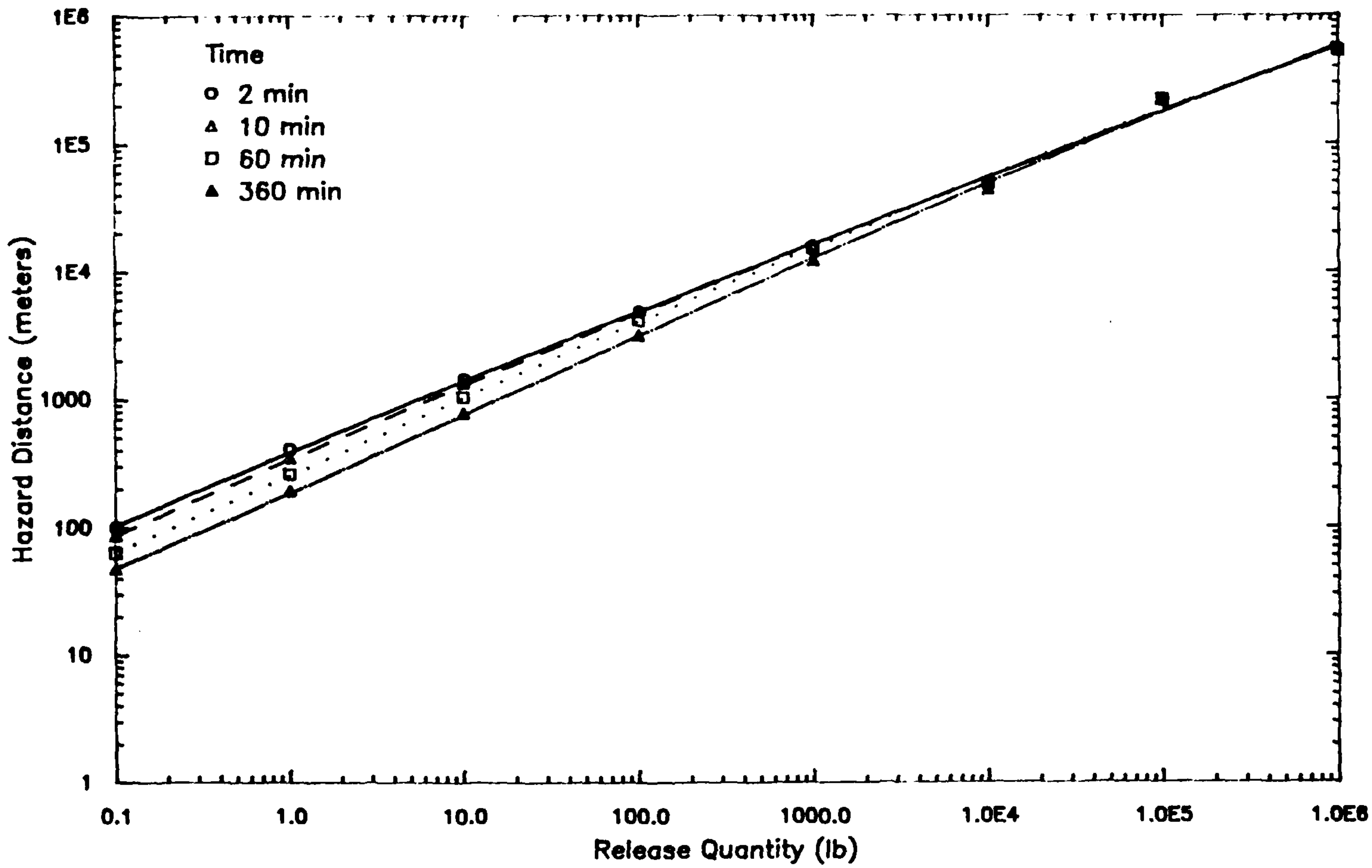


FIGURE B—13
HAZARD DISTANCES FOR GB
WC Weather, 1% Lethality
Semicontinuous Release Mode

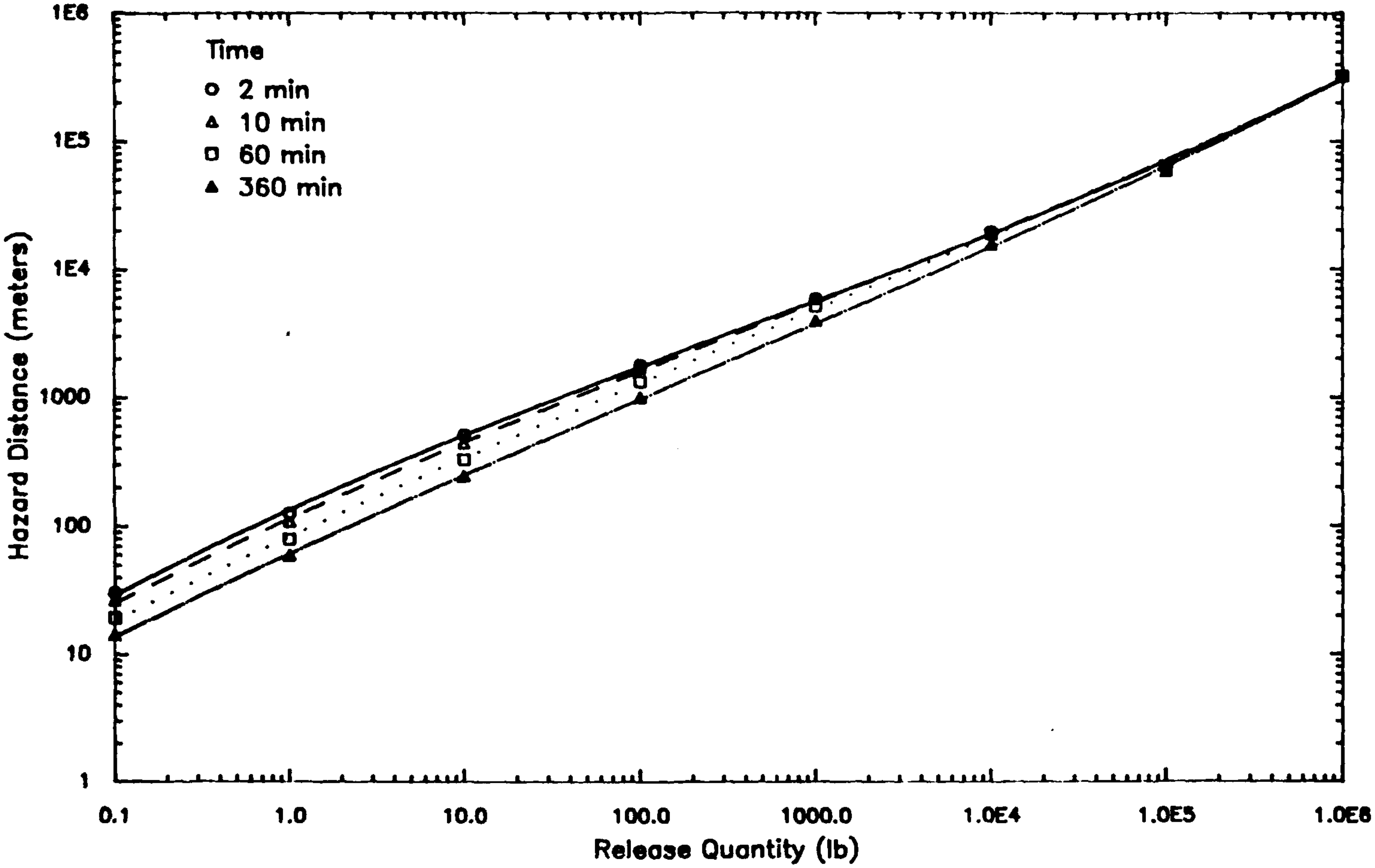


FIGURE B–14
HAZARD DISTANCES FOR GB
WC Weather, 50% Lethality
Semicontinuous Release Mode

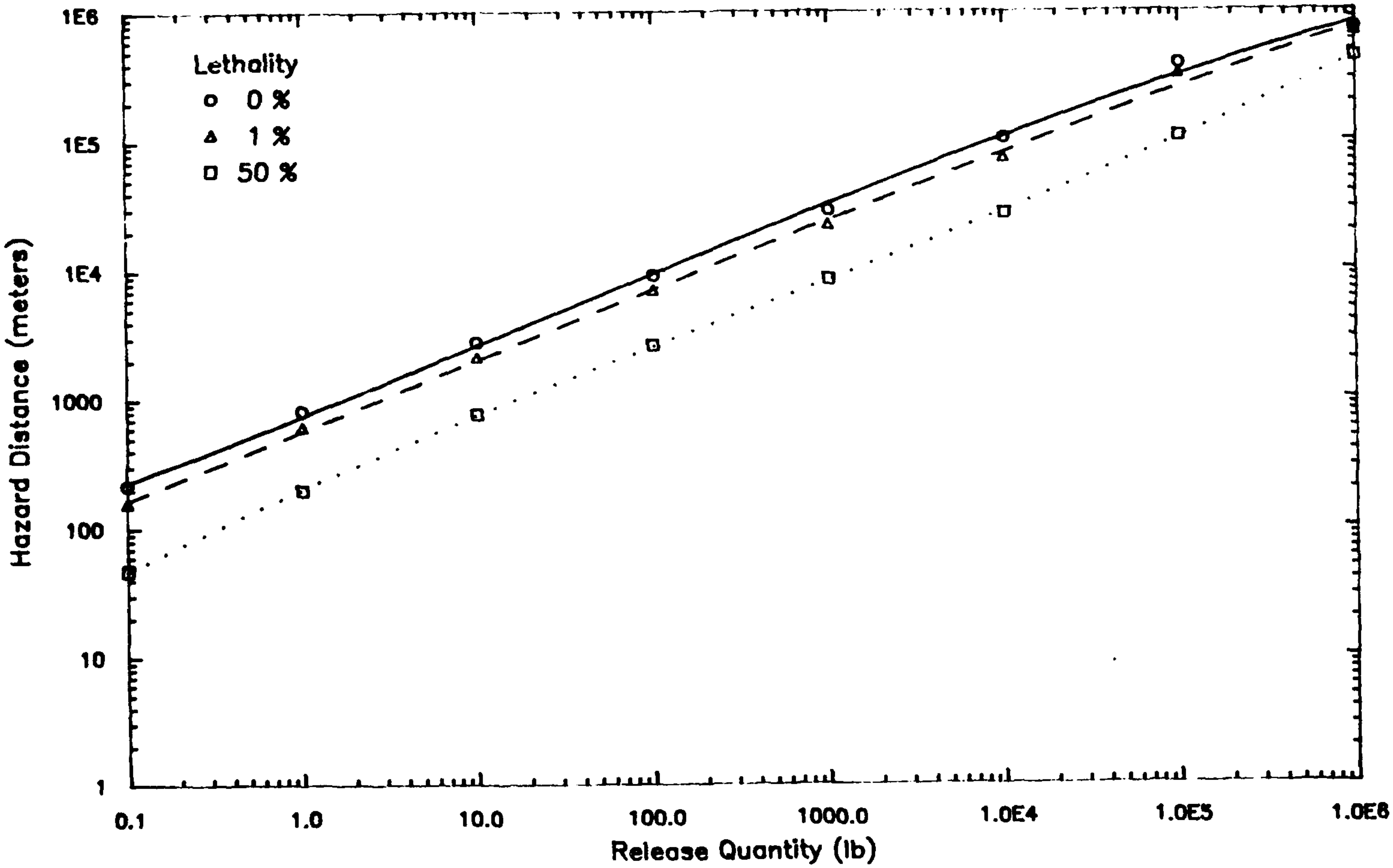


FIGURE B-15
HAZARD DISTANCES FOR GB
WC Weather, 0%, 1% and 50% Lethality
Instantaneous Release Mode

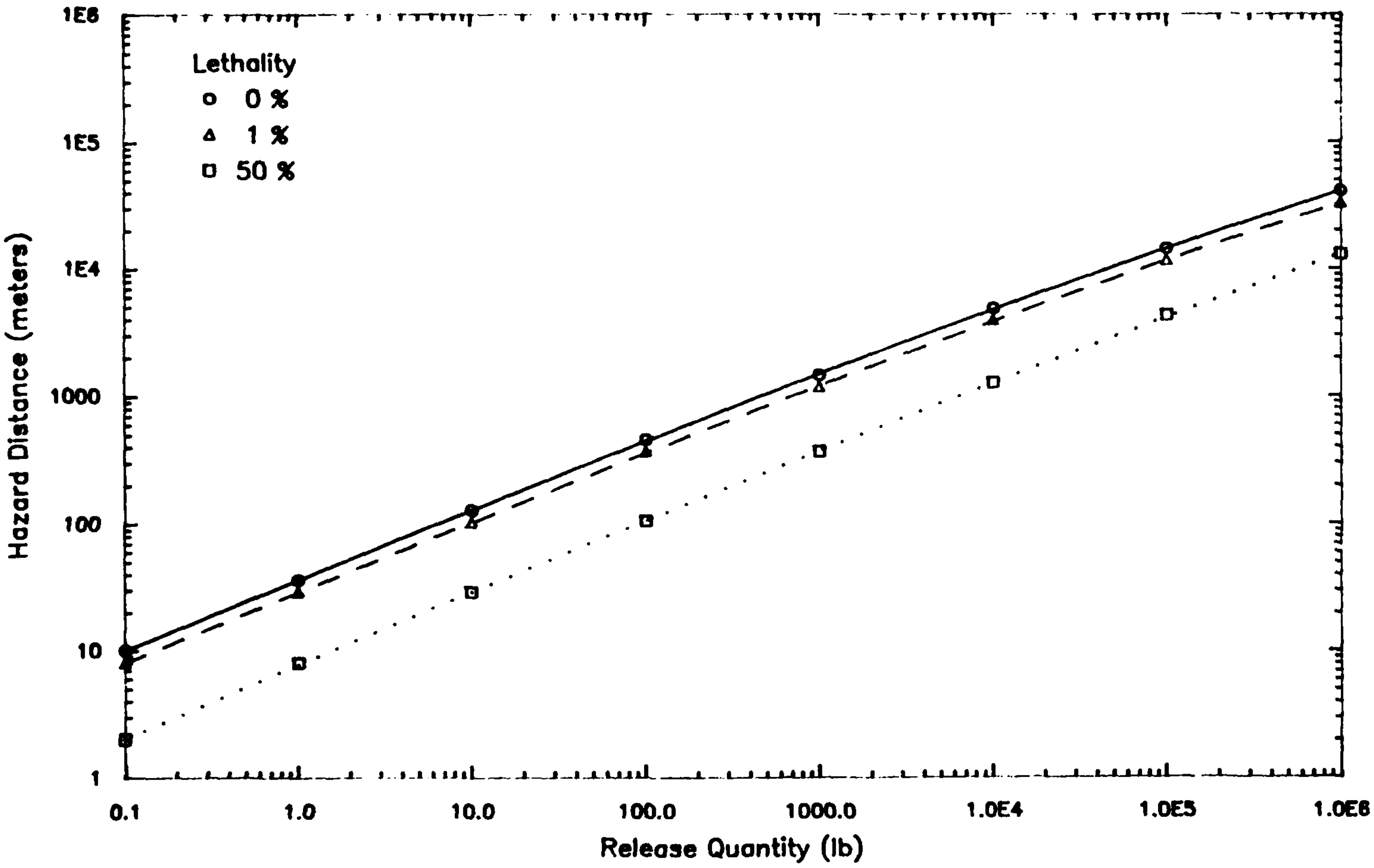


FIGURE B-16
HAZARD DISTANCES FOR HD
ML Weather 0%, 1% AND 50% Lethality

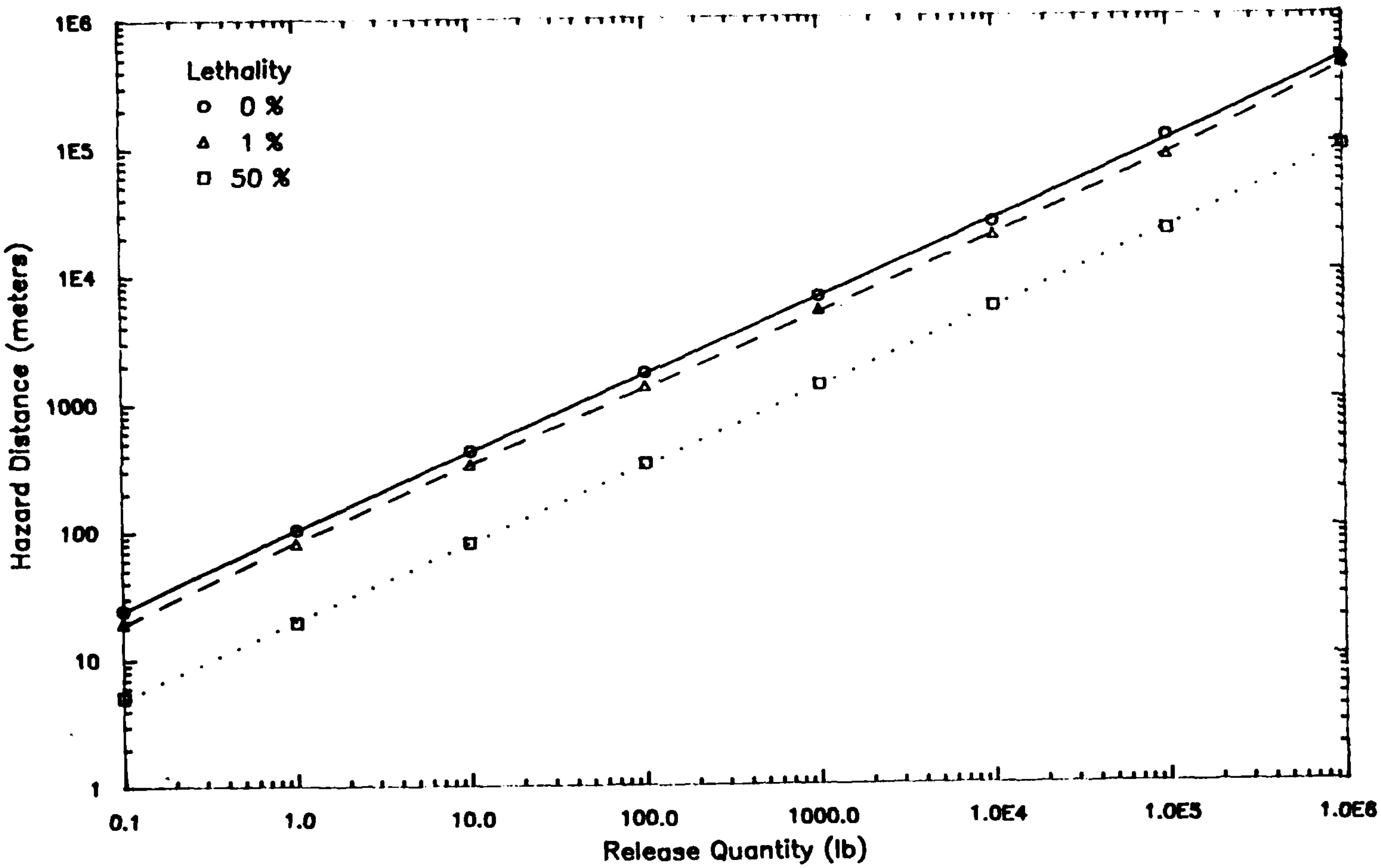


FIGURE B–17
HAZARD DISTANCES FOR HD
WC Weather, 0%, 1% and 50% Lethality

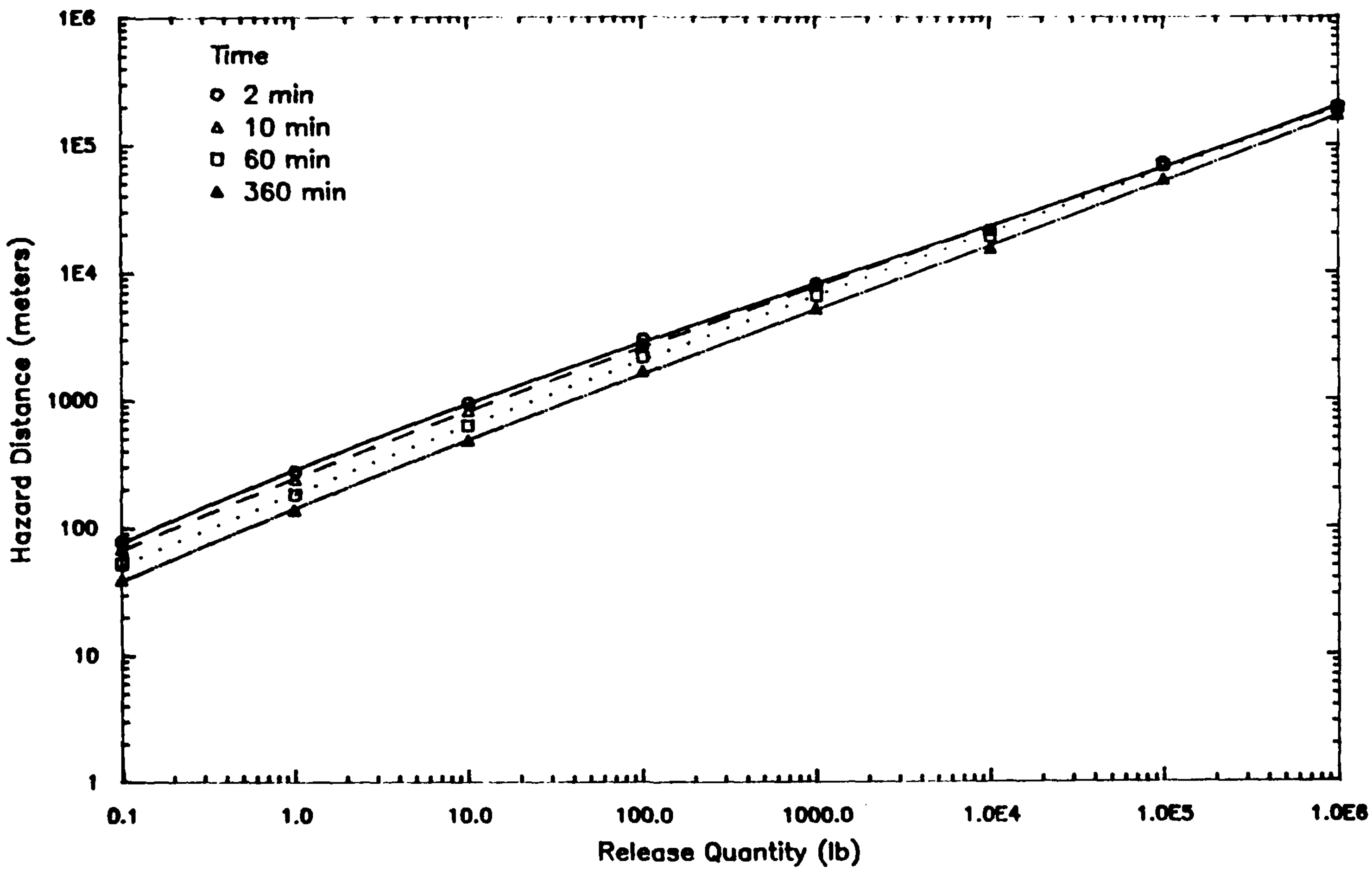


FIGURE B–18
HAZARD DISTANCES FOR VX
ML Weather, 0% Lethality

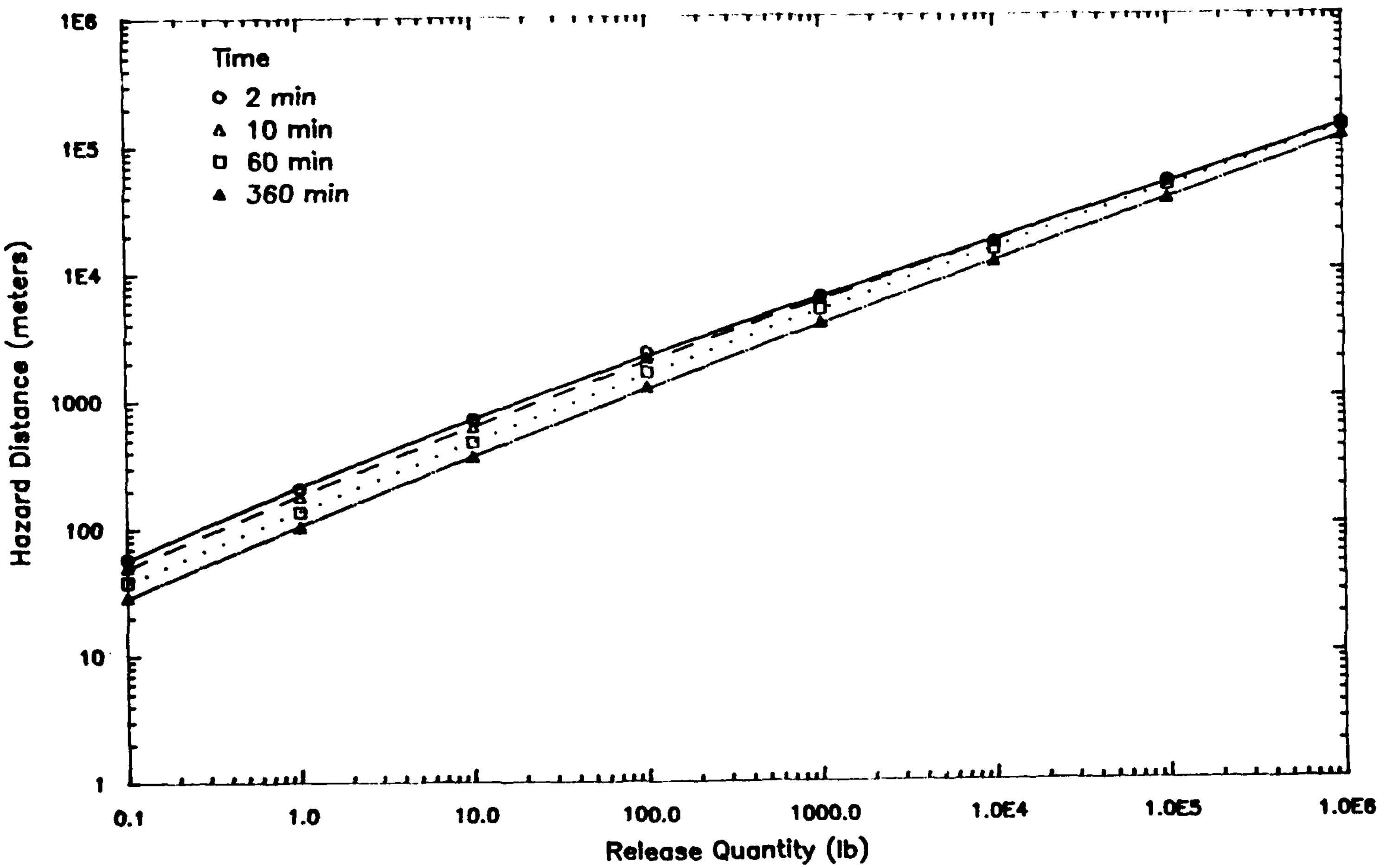


FIGURE B-19
HAZARD DISTANCES FOR VX
ML Weather, 1% Lethality

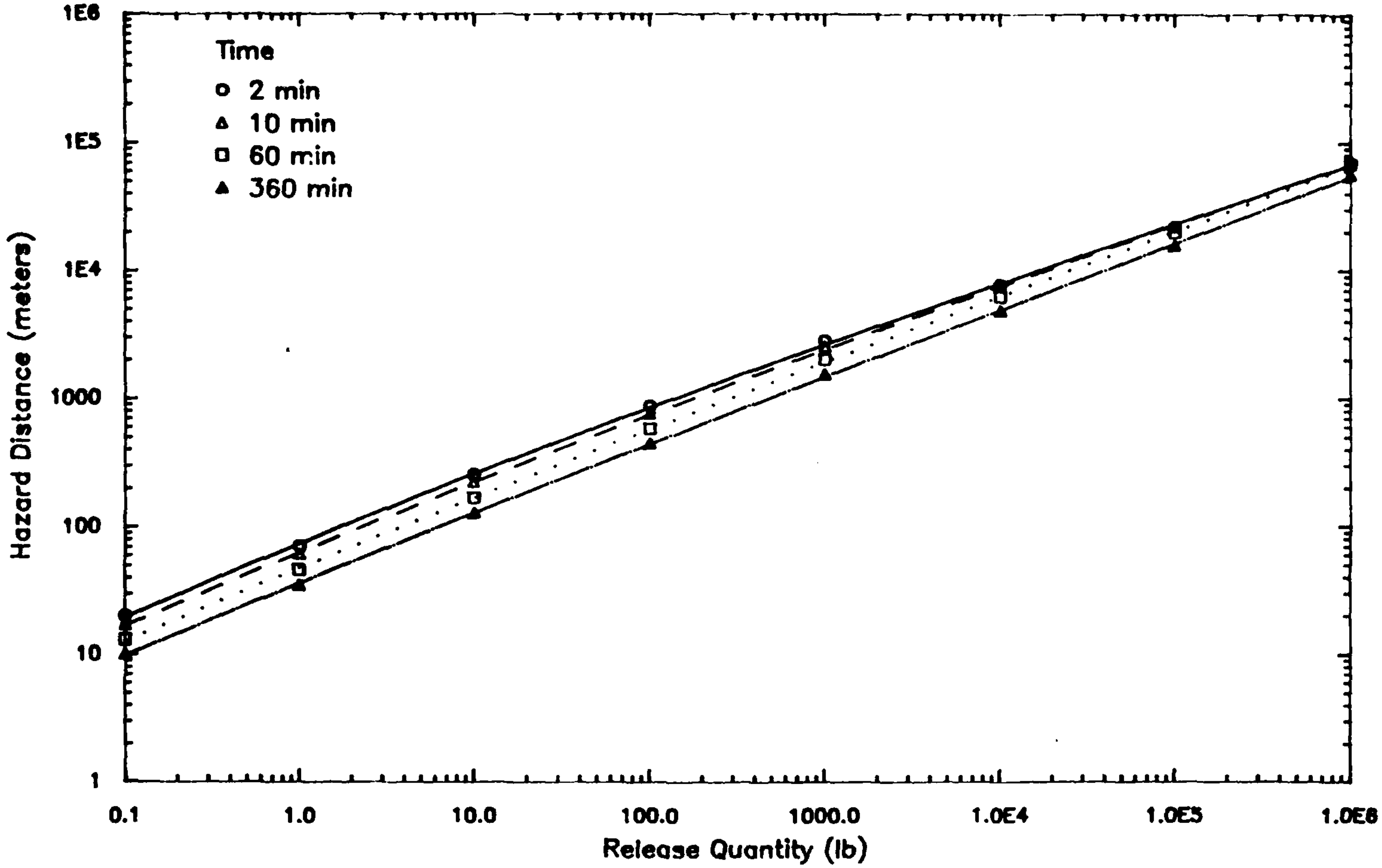


FIGURE B–20
HAZARD DISTANCES FOR VX
ML Weather, 50% Lethality

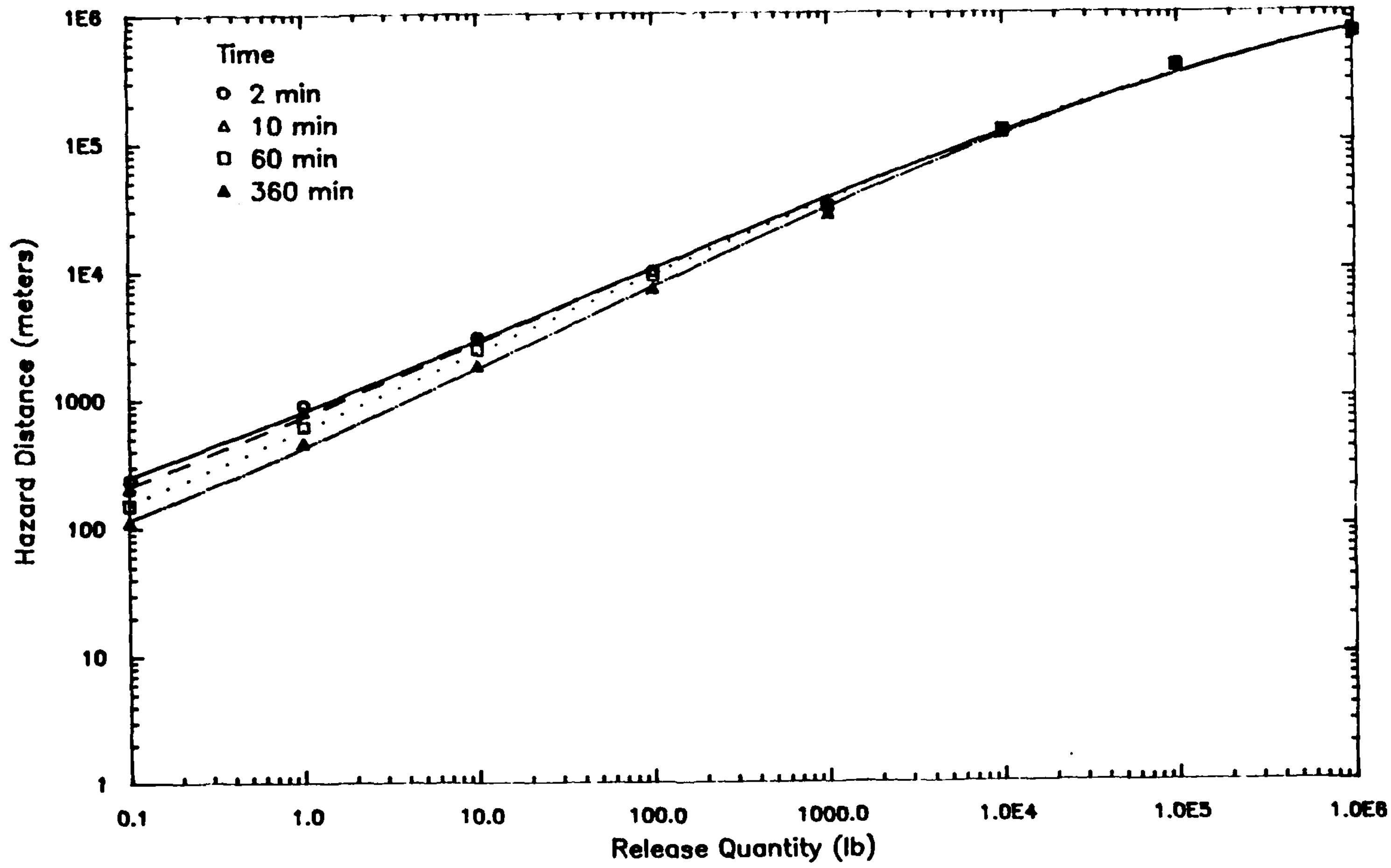


FIGURE B–21
HAZARD DISTANCES FOR VX
WC Weather, 0% Lethality

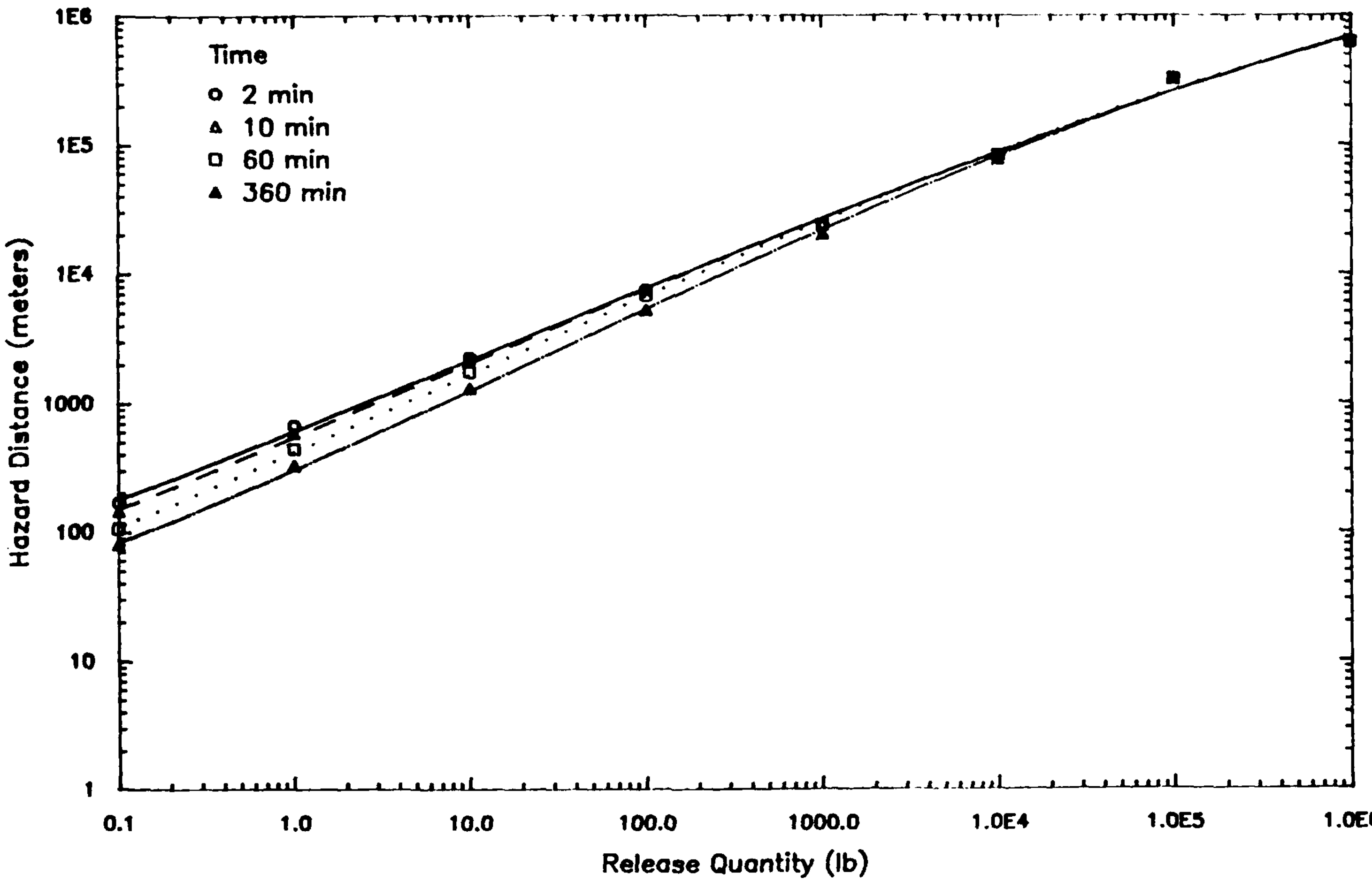


FIGURE B–22
HAZARD DISTANCES FOR VX
WC Weather, 1% Lethality

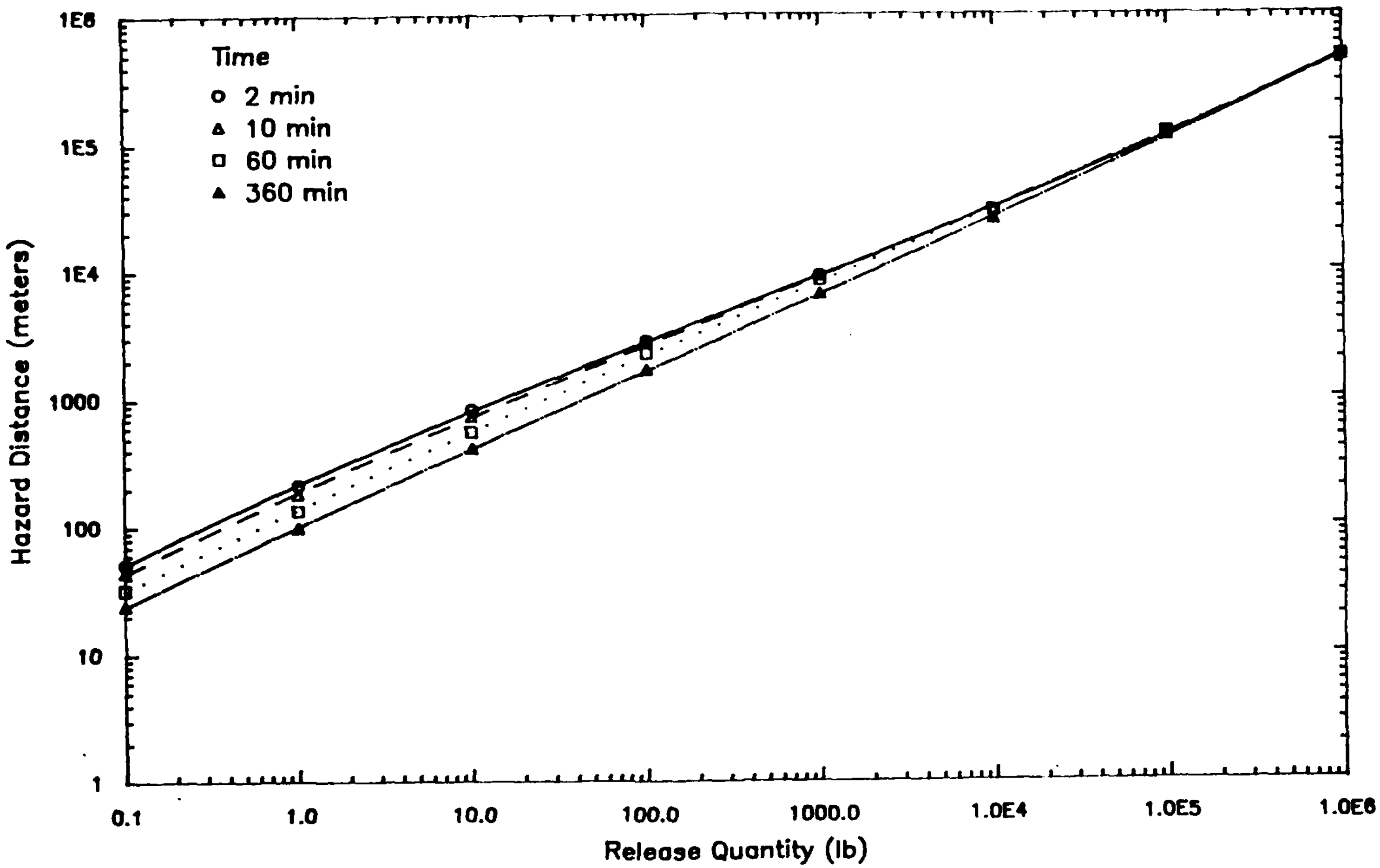


FIGURE B–23
HAZARD DISTANCES FOR VX
WC Weather, 50% Lethality

APPENDIX C

REFERENCE DATA

APPENDIX C: REFERENCE DATA

C.1 Introduction

This appendix contains data that is representative of the details that underlie the risk analysis. Much of the input data, including the accident scenario data base and the D2PC plume dispersion data, have been presented elsewhere in this report or in external docum. .ts and will not be repeated here. In this appendix, we will present those . .. .. data items that should assist the reader who wishes a detailed understanding of what was done in the risk analysis. In particular, the following data are presented:

- o Definition of disposal alternatives in terms of applicable activities;
- o Summary descriptions of the accident scenarios;
- o Fatality data as provided by ORNL;
- o Tabulated risk analysis data for a representative site.

C.2 Activity-Based Definition of Disposal Alternatives

Table C-1 illustrates how the disposal alternatives are defined, for the purpose of the risk analysis, in terms of the applicable activity codes. The single-letter codes used in Table C-1 for the designation of disposal alternatives and sites are defined in section 3.1.1. The two-letter codes used in the designation of activity (during which a potential accident is assumed to occur) are defined in Table A-1 of Appendix A.

The entries in Table C-1 indicate which activities (that is, which data files from the accident scenario data base) comprise the set of potential accidents for the alternative.

C.3 Summary Descriptions of Accident Scenarios

The accident scenario data provided by GA Technologies includes a textual description of each of the accident scenarios. The scenarios are identified by the activity code (first 2 characters of the scenario ID code -- see Table A-1) and the scenario number. For convenience, MITRE summarized the scenario descriptions provided by GA Technologies into a data base (dBASEIII) format. The results are presented in Table C-2. To facilitate finding a particular scenario description, the list is ordered alphabetically according to the ID. With only two exceptions, the scenario descriptions are independent of munition and agent type. Thus, any given

TABLE C-1
SITE/ALTERNATIVE/LOCAL (SAXX) Activity Selection File
- Originating Site Accidents -

ACTIVITY:

ALTERNATIVE	SITE	AT	BT	HA	HB	HF	HO	HR	HS	HW	PO	SA	SB	SL	SR	SW	VA	VB	VO	VR	VW	WB
** ALTERNATIVE: A	A					*	*				*								*			
	B					*	*				*								*			
	G	*		*								*					*					
	L	*		*								*					*					
	N					*	*				*								*			
	P					*	*				*								*			
	U					*	*				*								*			
** ALTERNATIVE: B	A					*	*				*								*			
	B					*	*				*								*			
	G		*		*								*					*				
	L		*		*								*					*				
	N					*	*				*								*			
	P					*	*				*								*			
	U					*	*				*								*			
** ALTERNATIVE: C	A					*	*				*								*			
	B					*	*				*								*			
	N					*	*				*								*			
	P					*	*				*								*			
	U					*	*				*								*			
** ALTERNATIVE: N	A							*							*					*		
	B							*							*					*		
	G							*							*					*		
	L							*							*					*		
	N							*							*					*		
	P							*							*					*		
	U							*							*					*		
** ALTERNATIVE: O	A					*	*				*								*			
	B					*	*				*								*			
	G					*	*				*								*			
	L					*	*				*								*			
	N					*	*				*								*			
	P					*	*				*								*			
	T					*	*				*								*			
	U					*	*				*								*			

TABLE C-1 (Continued)

SITE/ALTERNATIVE/LOCAL (SAXX) Activity Selection File
- Originating Site Accidents -

ACTIVITY:

	SITE:	AT	BT	HA	HB	HF	HO	HR	HS	HW	PO	SA	SB	SL	SR	SW	VA	VB	VO	VR	VW	WB
** ALTERNATIVE: R	B							*							*					*		
	G							*							*					*		
	L							*							*					*		
	N							*							*					*		
	P							*							*					*		
	U							*							*					*		
** ALTERNATIVE: S	A								*					*								
	B								*					*								
	G								*					*								
	L								*					*								
	N								*					*								
	P								*					*								
	T								*					*								
	U								*					*								
** ALTERNATIVE: W	A					*	*				*								*			
	B					*	*				*								*			
	G									*						*					*	*
	L					*	*				*								*			
	N					*	*				*								*			
	P					*	*				*								*			
	T					*	*				*								*			
	U					*	*				*								*			

TABLE C-1 (Continued)

SITE/ALTERNATIVE/LOCAL (SAXX) Activity Selection File
- Transportation Corridor Accidents -

ACTIVITY:

ALTERNATIVE	SITE:	AF	BF	RN	RR	WC	WI	WS
** ALTERNATIVE: A	G	*						
	L	*						
** ALTERNATIVE: B	G		*					
	L		*					
** ALTERNATIVE: C	G					*	*	*
	L		*					
** ALTERNATIVE: N	A			*				
	B			*				
	G			*				
	L			*				
	N			*				
	P			*				
	U			*				
** ALTERNATIVE: R	B				*			
	G				*			
	L				*			
	N				*			
	P			*				
	U			*				
** ALTERNATIVE: W	G					*	*	*

TABLE C-1 (Concluded)
SITE/ALTERNATIVE/LOCAL (SAXX) Activity Selection File
- Destination Site Accidents -

	SITE:	AL	BL	HA	HB	HF	HR	PO	SA	SB	SR	VA	VB	VO	VR
** ALTERNATIVE: A	T	*		*		*		*	*			*		*	
** ALTERNATIVE: B	T		*		*	*		*		*			*	*	
** ALTERNATIVE: C	T		*		*	*		*		*			*	*	
** ALTERNATIVE: N	T					*	*	*			*				*
** ALTERNATIVE: R	A					*	*	*			*				*
	T					*	*	*			*				*

TABLE C-2

CSDP/FEIS RISK ANALYSIS
- Accident Scenario Descriptions -
(Data File: MASTER4.DBF)
as of 15 October 1987

RECORD NUMBER	ID		SCENARIO
** AF			
384	AF	001	A severe ground collision involving an aircraft with munitions occurs and impact forces fail the agent package and munitions.
385	AF	002	A severe ground collision involving an aircraft with munitions occurs and impact forces fail the agent package and munitions. A subsequent fire occurs with a duration less than 2 h.
386	AF	003	A fire occurs aboard an aircraft with munitions and causes rupture of the compartment due to thermal expansion of the agent.
387	AF	004	A severe ground collision involving an aircraft with munitions occurs and impact forces fail the agent package and munitions. A subsequent fire occurs with a duration greater than 2 h.
388	AF	005	A moderate ground collision involving an aircraft with munitions occurs causing a breach of the package. A subsequent fire occurs causing a breach (by detonation or thermal expansion) of the agent compartment and agent is released.
** AL			
389	AL	001	A severe ground collision involving an aircraft with munitions occurs and impact forces fail the agent package and munitions.
390	AL	002	A severe ground collision involving an aircraft with munitions occurs and impact forces fail the agent package and munitions. A subsequent fire occurs with a duration less than 2 h.
391	AL	003	A fire occurs aboard an aircraft with munitions and causes rupture of the compartment due to thermal expansion of the agent.
392	AL	004	A severe ground collision involving an aircraft with munitions occurs and impact forces fail the agent package and munitions. A subsequent fire occurs with a duration greater than 2 h.
393	AL	005	A moderate ground collision involving an aircraft with munitions occurs causing a breach of the package. A subsequent fire occurs causing a breach (by detonation or thermal expansion) of the agent compartment and agent is released.
** AT			
394	AT	001	A severe ground collision involving an aircraft with munitions occurs and impact forces fail the agent package and munitions.
395	AT	002	A severe ground collision involving an aircraft with munitions occurs and impact forces fail the agent package and munitions. A subsequent fire occurs with a duration less than 2 h.
396	AT	003	A fire occurs aboard an aircraft with munitions and causes rupture of the compartment due to thermal expansion of the agent.
397	AT	004	A severe ground collision involving an aircraft with munitions occurs and impact forces fail the agent package and munitions. A subsequent fire occurs with a duration greater than 2 h.
398	AT	005	A moderate ground collision involving an aircraft with munitions occurs causing a breach of the package. A subsequent fire occurs causing a breach (by detonation or thermal expansion) of the agent compartment and agent is released.
** BF			
399	BF	001	A severe ground collision involving an aircraft with munitions occurs and impact forces fail the agent package and munitions.
400	BF	002	A severe ground collision involving an aircraft with munitions occurs and impact forces fail the agent package and munitions. A subsequent fire occurs with a duration less than 2 h.
401	BF	003	A fire occurs aboard an aircraft with munitions and causes rupture of the compartment due to thermal expansion of the agent.
402	BF	004	A severe ground collision involving an aircraft with munitions occurs and impact forces fail the agent package and munitions. A subsequent fire occurs with a duration greater than 2 h.

.E C-2 (Continued)

CSDP/FEIS RISK ANALYSIS
- Accident Scenario Descriptions -
(Data File: MASTER4.DBF)
as of 15 October 1987

RECORD NUMBER	ID		SCENARIO
403	BF	005	A moderate ground collision involving an aircraft with munitions occurs causing a breach of the package. A subsequent fire occurs causing a breach (by detonation or thermal expansion) of the agent compartment and agent is released.
** BL			
404	BL	001	A severe ground collision involving an aircraft with munitions occurs and impact forces fail the agent package and munitions.
405	BL	002	A severe ground collision involving an aircraft with munitions occurs and impact forces fail the agent package and munitions. A subsequent fire occurs with a duration less than 2 h.
406	BL	003	A fire occurs aboard an aircraft with munitions and causes rupture of the compartment due to thermal expansion of the agent.
407	BL	004	A severe ground collision involving an aircraft with munitions occurs and impact forces fail the agent package and munitions. A subsequent fire occurs with a duration greater than 2 h.
408	BL	005	A moderate ground collision involving an aircraft with munitions occurs causing a breach of the package. A subsequent fire occurs causing a breach (by detonation or thermal expansion) of the agent compartment and agent is released.
** BT			
409	BT	001	A severe ground collision involving an aircraft with munitions occurs and impact forces fail the agent package and munitions.
410	BT	002	A severe ground collision involving an aircraft with munitions occurs and impact forces fail the agent package and munitions. A subsequent fire occurs with a duration less than 2 h.
411	BT	003	A fire occurs aboard an aircraft with munitions and causes rupture of the compartment due to thermal expansion of the agent.
412	BT	004	A severe ground collision involving an aircraft with munitions occurs and impact forces fail the agent package and munitions. A subsequent fire occurs with a duration greater than 2 h.
413	BT	005	A moderate ground collision involving an aircraft with munitions occurs causing a breach of the package. A subsequent fire occurs causing a breach (by detonation or thermal expansion) of the agent compartment and agent is released.
** HA			
171	HA	001	Drop of bare pallet or single item at storage area.
221	HA	002	Forklift collision with short duration fire at storage area involving bare munitions.
173	HA	003	Forklift tine accident at storage area involving bare munitions.
175	HA	004	Forklift collision accident at storage area involving bare munitions.
177	HA	005	Drop of onsite container.
179	HA	006	Forklift collision accident with short duration fire during handling of onsite container.
181	HA	007	Forklift collision without fire during handling of onsite container.
183	HA	008	Drop of offsite container.
185	HA	009	Collision accident with short duration fire during handling of offsite container.
187	HA	010	Collision accident without fire during handling of offsite container.
189	HA	011	Drop of bare palletized munition leads to detonation.
191	HA	012	Forklift collision accident at storage area leads to detonation.
193	HA	017	Drop of pallet containing a leaking munition during leaker isolation operations.
195	HA	018	Drop of single leaking in leakers processing facility.
197	HA	019	Forklift tine puncture during leaker isolation.
199	HA	021	Collision accident without fire during handling of leaking munition.
201	HA	022	Drop of munition in onsite container leads to detonation.

TABLE C-2 (Continued)

CSDP/FEIS RISK ANALYSIS
- Accident Scenario Descriptions -
(Data File: MASTER4.DBF)
as of 15 October 1987

RECORD NUMBER	ID	SCENARIO
203	HA 023	Drop of munition in offsite container leads to detonation.
205	HA 024	Collision accident during munition handling in onsite container leads to detonation.
207	HA 025	Collision accident during munition handling in offsite container leads to detonation.
209	HA 026	Collision accident in onsite container with prolonged fire lead to thermal detonation.
211	HA 027	Collision accident in offsite container with prolonged fire lead to thermal detonation.
213	HA 029	Drop of pallet containing leaker leads to detonation.
215	HA 030	Drop of single leaking munitions leads to detonation.
217	HA 031	Collision accident involving a leaking munitions leads to detonation.
219	HA 032	Failure to detect a leak in the offsite container.
** HB		
414	HB 001	Drop of bare pallet or single item at storage area.
415	HB 002	Forklift collision with short duration fire at storage area involving bare munitions.
416	HB 003	Forklift tine accident at storage area involving bare munitions.
417	HB 004	Forklift collision accident at storage area involving bare munitions.
418	HB 005	Drop of onsite container.
419	HB 006	Forklift collision accident with short duration fire during handling of onsite container.
420	HB 007	Forklift collision without fire during handling of onsite container.
421	HB 008	Drop of offsite container.
422	HB 009	Collision accident with short duration fire during handling of offsite container.
423	HB 010	Collision accident without fire during handling of offsite container.
424	HB 011	Drop of bare palletized munition leads to detonation.
425	HB 012	Forklift collision accident at storage area leads to detonation.
426	HB 017	Drop of pallet containing a leaking munition during leaker isolation operations.
427	HB 018	Drop of single leaking in leakers processing facility.
428	HB 019	Forklift tine puncture during leaker isolation.
429	HB 021	Collision accident without fire during handling of leaking munition.
430	HB 022	Drop of munition in onsite container leads to detonation.
431	HB 023	Drop of munition in offsite container leads to detonation.
432	HB 024	Collision accident during munition handling in onsite container leads to detonation.
433	HB 025	Collision accident during munition handling in offsite container leads to detonation.
434	HB 026	Collision accident in onsite container with prolonged fire lead to thermal detonation.
435	HB 027	Collision accident in offsite container with prolonged fire lead to thermal detonation.
436	HB 029	Drop of pallet containing leaker leads to detonation.
437	HB 030	Drop of single leaking munitions leads to detonation.
438	HB 031	Collision accident involving a leaking munitions leads to detonation.
439	HB 032	Failure to detect a leak in the offsite container.
** HF		
223	HF 001	Munition pallet or container dropped during movement from MHI to MDB.
12	HF 002	Bare single munition dropped during handling inside the MDB.
224	HF 003	Forklift collision accident with short duration fire during handling from MHI to MDB.
225	HF 004	Forklift tine accident handling from the MHI to MDB.
226	HF 005	Collision accident with prolonged fire during handling from MHI to MDB leads to detonation or hydraulic rupture.
227	HF 007	Collision accident without fire.

..E C-2 (Continued)

CSDP/FEIS RISK ANALYSIS
- Accident Scenario Descriptions -
(Data File: MASTER4.DBF)
as of 15 October 1987

	RECORD NUMBER	ID		SCENARIO
	228	HF	008	Munition dropped inside the MDB.
	229	HF	009	Forklift tine accident inside the MDB.
	13	HF	010	Collision without fire inside the MDB.
	230	HF	011	Drop of munition pallet from the MHI to MDB leads to detonation.
	231	HF	012	Drop of bare single munition inside the MDB leads to detonation.
	232	HF	013	Drop of palletized munition (in container) inside the MDB leads to detonation.
	233	HF	014	Collision accident from the MHI to the MDB leads to detonation.
** HO				
	1	HO	001	Drop of bare pallet or single item at storage area.
	2	HO	002	Forklift collision with short duration fire at storage area involving bare munitions.
	3	HO	003	Forklift tine accident involving bare munitions at storage area.
	4	HO	004	Forklift collision accident without fire at storage area involving bare munitions.
	5	HO	005	Drop of onsite container.
	6	HO	006	Forklift collision with short duration fire during handling of onsite container.
	7	HO	007	Forklift collision without fire during handling of onsite container.
	8	HO	011	Drop of bare palletized munition leads to detonation.
	9	HO	012	Forklift collision accident at storage area leads to detonation of burstered munition.
	10	HO	024	Collision accident during munition handling in onsite container leads to detonation due to impact.
	11	HO	026	Collision accident in onsite container with prolonged fire leads to thermal detonation.
	490	HO	027	Collision accident in offsite container with prolonged fire leads to thermal detonation.
	491	HO	028	Drop of single munitions at maintenance facility leads to detonation.
	492	HO	029	Drop of pallet containing leaker leads to detonation.
	493	HO	030	Drop of single leaking munition leads to detonation.
	494	HO	031	Collision accident involving a leaker leads to detonation due to impact.
	495	HO	032	Failure to detect a leak in the offsite container.
** HR				
	440	HR	001	Drop of bare pallet or single item at storage area.
	441	HR	002	Forklift collision with short duration fire at storage area involving bare munitions.
	442	HR	003	Forklift tine accident at storage area involving bare munitions.
	443	HR	004	Forklift collision accident at storage area involving bare munitions.
	444	HR	005	Drop of onsite container.
	445	HR	006	Forklift collision accident with short duration fire during handling of onsite container.
	446	HR	007	Forklift collision without fire during handling of onsite container.
	447	HR	008	Drop of offsite container.
	448	HR	009	Collision accident with short duration fire during handling of offsite container.
	449	HR	010	Collision accident without fire during handling of offsite container.
	450	HR	011	Drop of bare palletized munition leads to detonation.
	451	HR	012	Forklift collision accident at storage area leads to detonation.
	452	HR	017	Drop of pallet containing a leaking munition during leaker isolation operations.
	453	HR	018	Drop of single leaking in leakers processing facility.
	454	HR	019	Forklift tine puncture during leaker isolation.
	455	HR	021	Collision accident without fire during handling of leaking munition.
	456	HR	022	Drop of munition in onsite container leads to detonation.

TABLE C-2 (Continued)

CSDP/FEIS RISK ANALYSIS
- Accident Scenario Descriptions -
(Data File: MASTER4.DBF)
as of 15 October 1987

RECORD NUMBER	ID		SCENARIO
457	HR	023	Drop of munition in offsite container leads to detonation.
458	HR	024	Collision accident during munition handling in onsite container leads to detonation.
459	HR	025	Collision accident during munition handling in offsite container leads to detonation.
460	HR	026	Collision accident in onsite container with prolonged fire lead to thermal detonation.
461	HR	027	Collision accident in offsite container with prolonged fire lead to thermal detonation.
462	HR	029	Drop of pallet containing leaker leads to detonation.
463	HR	030	Drop of single leaking munitions leads to detonation.
464	HR	031	Collision accident involving a leaking munitions leads to detonation.
465	HR	032	Failure to detect a leak in the offsite container.
** HS			
478	HS	001	Drop of pallet or container in storage area or maintenance facility; munition punctured.
479	HS	002	Forklift collision with short duration fire.
480	HS	003	Forklift tine puncture.
481	HS	004	Forklift collision without fire.
482	HS	005	Drop of munition leads to detonation.
483	HS	006	Collision accident leads to detonation.
484	HS	007	Collision accident with prolonged fire.
485	HS	008	Munition pallet dropped during pallet inspection.
486	HS	009	Forklift tine puncture during pallet inspection.
487	HS	010	Forklift collision during pallet inspection.
488	HS	011	Munition pallet dropped during pallet inspection; detonation occurs.
489	HS	012	Forklift collision; detonation occurs.
** HW			
172	HW	001	Drop of bare pallet or single item at storage area.
222	HW	002	Forklift collision with short duration fire at storage area involving bare munitions.
174	HW	003	Forklift tine accident at storage area involving bare munitions.
176	HW	004	Forklift collision accident at storage area involving bare munitions.
178	HW	005	Drop of onsite container.
180	HW	006	Forklift collision accident with short duration fire during handling of onsite container.
182	HW	007	Forklift collision without fire during handling of onsite container.
184	HW	008	Drop of offsite container.
186	HW	009	Collision accident with short duration fire during handling of offsite container.
188	HW	010	Collision accident without fire during handling of offsite container.
190	HW	011	Drop of bare palletized munition leads to detonation.
192	HW	012	Forklift collision accident at storage area leads to detonation.
194	HW	017	Drop of pallet containing a leaking munition during leaker isolation operations.
196	HW	018	Drop of single leaking in leakers processing facility.
198	HW	019	Forklift tine puncture during leaker isolation.
200	HW	021	Collision accident without fire during handling of leaking munition.
202	HW	022	Drop of munition in onsite container leads to detonation.
204	HW	023	Drop of munition in offsite container leads to detonation.
206	HW	024	Collision accident during munition handling in onsite container leads to detonation.
208	HW	025	Collision accident during munition handling in offsite container leads to detonation.

.LE C-2 (Continued)

CSDP/FEIS RISK ANALYSIS
- Accident Scenario Descriptions -
(Data File: MASTER4.DBF)
as of 15 October 1987

RECORD NUMBER	ID		SCENARIO
210	HW	026	Collision accident in onsite container with prolonged fire lead to thermal detonation.
212	HW	027	Collision accident in offsite container with prolonged fire lead to thermal detonation.
214	HW	029	Drop of pallet containing leaker leads to detonation.
216	HW	030	Drop of single leaking munitions leads to detonation.
218	HW	031	Collision accident involving a leaking munitions leads to detonation.
220	HW	032	Failure to detect a leak in the offsite container.
512	HW	034	Drop of lighter while loading with shipboard crane crushes vault.
** PO			
342	PO	001	Tornado-generated missile puncture/crush munitions in the MHI.
343	PO	002	Tornado-generated missile detonate munitions in the MHI.
344	PO	003	Tornado-generated missile puncture/crush munitions in the UPA.
345	PO	004	Tornado-generated missile detonate munitions in the UPA.
346	PO	005	Tornado-generated missile damages the agent piping system between the BDS and TOX at TEAD (bulk-only facility).
347	PO	006	Meteorite strikes the MHI.
348	PO	007	Meteorite strikes the UPA.
350	PO	008	Meteorite strikes the agent piping system between the BDS and TOX at TEAD (bulk-only facility).
351	PO	009	Direct large aircraft crash onto the MHI, no fire.
280	PO	010	Direct large aircraft crash onto the MHI; fire not contained in 0.5 hours
281	PO	011	Direct large aircraft crash onto the MHI; fire contained in 0.5 hours
282	PO	012	Direct large aircraft crash damages the MDB; no fire
283	PO	013	Direct large aircraft crash damages the MDB; fire not contained in 0.5 hours
284	PO	014	Direct large aircraft crash damages the MDB; fire contained in 0.5 hours
285	PO	015	Indirect large aircraft crash damages the MHI; no fire
286	PO	016	Indirect large aircraft crash damages the MHI; fire not contained in 0.5 hours
287	PO	017	Indirect large aircraft crash damages the MHI; fire contained in 0.5 hours
288	PO	018	Indirect large aircraft crash damages the MDB; no fire
289	PO	019	Indirect large aircraft crash damages the MDB; fire not contained in 0.5 hours
290	PO	020	Indirect large aircraft crash damages the MDB; fire contained in 0.5 hours
352	PO	021	Direct crash of a large or small aircraft damages the outdoor agent piping system at TEAD, no fire.
353	PO	022	Direct crash of a large or small aircraft damages the outdoor agent piping system at TEAD, fire occurs and not contained.
354	PO	023	Earthquake causes the munitions in the MHI to fall and be punctured.
355	PO	024	Earthquake causes munitions in the MHI to fall and detonate.
356	PO	025	Earthquake damages the MDB structure, munitions fall and are punctured, fire suppressed.
357	PO	026	Earthquake damages the MDB structure, munitions fall and are punctured, earthquake also initiates fire, fire suppression system fails.
359	PO	028	Earthquake damages the MDB structure, munitions fall and are punctured, TOX damaged, fire occurs, fire suppression system fails.
291	PO	029	Earthquake damages the MDB; munitions are intact; fire occurs; fire suppression system fails
360	PO	030	Earthquake damages the MDB, munitions are intact, TOX damaged, no fire occurs.
362	PO	031	Earthquake damages the MDB, munitions are intact, TOX damaged, fire occurs, fire not suppressed.
363	PO	032	Earthquake causes munitions to fall and detonate, MDB breached by detonation, the TOX is intact, no fire.
364	PO	033	Earthquake causes munitions to fall but no detonation occurs, the MDB is intact, the TOX is intact, earthquake also initiates fire, fire suppression system fails.

TABLE C-2 (Continued)

CSDP/FEIS RISK ANALYSIS
- Accident Scenario Descriptions -
(Data File: MASTER4.DBF)
as of 15 October 1987

RECORD NUMBER	ID		SCENARIO
365	PO	034	Earthquake causes munitions to fall but no detonation occurs, the MDB is intact, the TOX is damaged, fire occurs, fire suppression system fails.
234	PO	041	Failure to stop agent feed to the LIC, overloads the ventilation system.
235	PO	042	MPF explosion due to failure to stop fuel flow after a shutdown.
236	PO	043	MPF explosion due to hydraulic rupture of an unpunched bulk item. MPF room and ventilation integrity maintained.
237	PO	044	MPF explosion due to hydraulic rupture of an unpunched bulk item. MPF room or ventilation integrity lost.
238	PO	045	Ton container is spilled in the ECV, MDB structure fails due to subsequent agent fire.
239	PO	046	Munition detonation in the ECV, no fire.
240	PO	047	Munition detonation in the ECV, fire results but does not propagate.
241	PO	048	Munition detonation in the ECV, fire results and propagates.
242	PO	049	Munition detonation in ECR causes structural and ventilation system failure.
243	PO	050	Munition detonation in ECR causes structural failure, a fire, and ventilation failure.
244	PO	051	Ton container spill in the MPB results in fire and structural failure.
249	PO	052	A burstered munition is fed to the DUN.
266	PO	052	A burstered munition is fed to the DUN.
349	PO	A07	Meteorite strikes the TOX.
358	PO	A28	Earthquake damages the MDB structure, munitions fall and are punctured, TOX damaged, fire occurs, fire suppressed.
361	PO	A31	Earthquake damages the MDB, munitions are intact, TOX damaged, fire occurs, fire suppressed.
** RN			
496	RN	001	A train accident involving a munitions railcar occurs and crush forces fail the agent containment.
497	RN	002	A train accident involving a munitions railcar occurs and impact forces fail the agent containment.
120	RN	003	A train accident involving a munitions railcar occurs and puncture forces fail the agent containment.
121	RN	004	A train accident with fire occurs. Either the package insulation is torn away due to mechnical forces and the fire is able to heat the munitions inside the package, or the fire last long enough to cause burstered munitions in the package to detonate. Undue force created by the accident may also cause burster detonation.
122	RN	005	A train accident with fire occurs. Either the package insulation is torn away due to mechanical forces and the fire is able to heat the munitions inside the package, or the fire lasts long enough to cause thermal ruture of the munitions inside the package.
123	RN	006	An aircraft crashes on a munitions railcar. No fire occurs, but impact forces lead to detonations and/or failure of agent containment.
124	RN	007	An aircraft crashes on a munitions railcar. Fire occurs, but impact forces lead to detonations and/or failure of agent containment.
498	RN	008	Combined with scenario RN007.
499	RN	009	A severe earthquake occurs involving a munitions railcar and crush forces fail the agent containment.
500	RN	010	A severe earthquake occurs involving a munitions railcar and impact forces fail the agent containment.
125	RN	011	A severe earthquake occurs involving a munitions railcar and puncture forces fail the agent containment.
126	RN	012	A severe earthquake occurs involving a munitions railcar and subsequent fire detonates burstered.
127	RN	013	A severe earthquake occurs involving a munitions railcar and subsequent fire fails nonburstered munitions.
128	RN	014	A tornado-generate missile leads to failure of the agent containment, or a tornado occurs, causing overturn or derailment of a munitions railcar.
129	RN	015	A earthquake or a tornado occurs, generating undue mechanical forces which cause detonation of burstered munitions.
** RR			
501	RR	001	A train accident involving a munitions railcar occurs and crush forces fail the agent containment.

.E C-2 (Continued)
CSDP/FEIS RISK ANALYSIS
- Accident Scenario Descriptions -
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RECORD NUMBER	ID		SCENARIO
502	RR	002	A train accident involving a munitions railcar occurs and impact forces fail the agent containment.
267	RR	003	A train accident involving a munitions railcar occurs and puncture forces fail the agent containment.
268	RR	004	A train accident with fire occurs. Either the package insulation is torn away due to mechnical forces and the fire is able to heat the munitions inside the package, or the fire last long enough to cause burstered munitions in the package to detonate. Undue force created by the accident may also cause burster detonation.
269	RR	005	A train accident with fire occurs. Either the package insulation is torn away due to mechanical forces and the fire is able to heat the munitions inside the package, or the fire lasts long enough to cause thermal ruture of the munitions inside the package.
270	RR	006	An aircraft crashes on a munitions railcar. No fire occurs, but impact forces lead to detonations and/or failure of agent containment.
271	RR	007	An aircraft crashes on a munitions railcar. Fire occurs, but impact forces lead to detonations and/or failure of agent containment.
503	RR	008	Combined with scenario RN007.
504	RR	009	A severe earthquake occurs involving a munitions railcar and crush forces fail the agent containment.
505	RR	010	A severe earthquake occurs involving a munitions railcar and impact forces fail the agent containment.
272	RR	011	A severe earthquake occurs involving a munitions railcar and puncture forces fail the agent containment.
273	RR	012	A severe earthquake occurs involving a munitions railcar and subsequent fire detonates burstered.
274	RR	013	A severe earthquake occurs involving a munitions railcar and subsequent fire fails nonburstered munitions.
275	RR	014	A tornado-generate missile leads to failure of the agent containment, or a tornado occurs, causing overturn or derailment of a munitions failcar.
276	RR	015	A earthquake or a tornado occurs, generating undue mechanical forces which cause detonation of burstered munitions.

** SA

RECORD NUMBER	ID		SCENARIO
366	SA	001	Large aircraft direct crash onto transportation containers in holding area; no fire.
367	SA	002	Large aircraft direct crash onto transportation containers in holding area, fire not contained.
368	SA	003	Large aircraft direct crash onto transportation containers in holding area; fire contained.
369	SA	004	Small aircraft direct crash onto transportation containers in holding area; no fire.
370	SA	005	Small aircraft direct crash onto transportation containers in holding area; fire not contained.
371	SA	006	Small aircraft direct crash onto transportation containers in holding area; fire contained.
372	SA	007	Tornado-generated missiles strike munitions in transportation containers in holding area; no detonation.
373	SA	008	Tornado-generated missiles strike munitions in holding area; detonation occurs.
374	SA	009	Meteorite strikes munitions in transportation containers in holding area; fire occurs; detonation (if burstered).

** SB

RECORD NUMBER	ID		SCENARIO
375	SB	001	Large aircraft direct crash onto transportation containers in holding area; no fire.
376	SB	002	Large aircraft direct crash onto transportation containers in holding area, fire not contained.
377	SB	003	Large aircraft direct crash onto transportation containers in holding area; fire contained.
378	SB	004	Small aircraft direct crash onto transportation containers in holding area; no fire.
379	SB	005	Small aircraft direct crash onto transportation containers in holding area; fire not contained.
380	SB	006	Small aircraft direct crash onto transportation containers in holding area; fire contained.
381	SB	007	Tornado-generated missiles strike munitions in transportation containers in holding area; no detonation.
382	SB	008	Tornado-generated missiles strike munitions in holding area; detonation occurs.
383	SB	009	Meteorite strikes munitions in transportation containers in holding area; fire occurs; detonation (if burstered).

TABLE C-2 (Continued)

CSDP/FEIS RISK ANALYSIS
- Accident Scenario Descriptions -
(Data File: MASTER4.DBF)
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** SL

RECORD NUMBER	ID		SCENARIO
292	SL	001	Munitions develops a leak during the in between inspection period.
293	SL	002	Munition punctured by forklift tine during leaker-handling activities.
294	SL	003	Spontaneous ignition of rocket during storage (not analyzed for lack of quantitative data).
295	SL	004	Large aircraft direct crash onto storage area; fire not contained in 30 min. (Note: Assume detonation occurs if burstered munitions hit, fire involving burstered munitions not contained at all.
296	SL	005	Large aircraft indirect crash onto storage area; fire not contained in 30 min. (See note in SL4.)
297	SL	006	Tornado-generated missiles strike the storage magazine, warehouse, or open storage area; munitions breached (no detonation).
298	SL	007	Severe earthquake breaches the munitions in storage igloos, no detonations.
299	SL	008	Meteorite strikes the storage area; fire occurs; munitions breached (if burstered, detonation also occurs).
300	SL	009	Munition dropped during leaker isolation operation, munition punctured.
301	SL	010	Storage igloo or warehouse fire from internal sources.
302	SL	011	Munitions are dropped due to pallet degradation.
303	SL	012	Liquid petroleum gas (LPG) infiltrates igloo/building.
304	SL	013	Flammable liquids stored in nearby facilities explode, fire propagates to munition warehouse (applies to NAAP).
305	SL	014	Tornado-induced building collapse leads to breaching/detonation of munitions.
306	SL	015	Small aircraft direct crash onto warehouse or open storage yard, fire occurs, not contained in 30 min.
307	SL	016	Large aircraft direct crash, no fire, detonation (if burstered).
308	SL	017	Large aircraft direct crash, fire contained within 30 min (applies to nonburstered munitions only).
309	SL	018	Small aircraft direct crash onto warehouse or open storage yard, no fire.
310	SL	019	Small aircraft direct crash onto warehouse or open storage yard, fire contained in 30 min.
311	SL	020	Large aircraft indirect crash onto storage area, no fire.
312	SL	021	Large aircraft indirect crash onto storage area, fire contained in 30 min.
313	SL	022	Severe earthquake leads to munition detonation.
314	SL	023	Tornado-generated missiles strike the storage igloo and leads to munition detonation.
315	SL	024	Lightning strikes ton containers stored outdoors.
316	SL	025	Munition dropped during leaker isolation, munition detonates.
317	SL	A26	Earthquake occurs, NAAP warehouse is intact, no ton containers damaged, fire occurs.
322	SL	A27	Earthquake occurs, TEAD warehouses intact, munitions intact, fire occurs at one warehouse.
327	SL	A28	Earthquake occurs, UMDA warehouses intact, munitions intact, fire occurs at one warehouse.
318	SL	B26	Earthquake occurs, NAAP warehouse is intact, ton container damaged, no fire.
323	SL	B27	Earthquake occurs, TEAD warehouses intact, munitions intact, fire occurs at two warehouses.
328	SL	B28	Earthquake occurs, UMDA warehouses intact, munitions intact, fire occurs at two warehouses.
319	SL	C26	Earthquake occurs, NAAP warehouse is intact, ton container damaged, fire occurs.
324	SL	C27	Earthquake occurs, one TEAD warehouse is damaged, munitions intact, fire occurs at one warehouse.
329	SL	C28	Earthquake occurs, UMDA warehouses intact, munitions in one warehouse damaged, no fire occurs.
320	SL	D26	Earthquake occurs, NAAP warehouse is damaged, ton containers damaged, fire occurs.
325	SL	D27	Earthquake occurs, one TEAD warehouse is damaged, munitions intact, fire occurs at two warehouse.
330	SL	D28	Earthquake occurs, UMDA warehouses intact, munitions in one warehouse damaged, fire occurs at warehouse with damaged munitions.
321	SL	E26	Earthquake occurs, NAAP warehouse is damaged, ton containers damaged, no fire occurs.
326	SL	E27	Earthquake occurs, two TEAD warehouses damaged, munitions intact, fire occurs at one warehouse.

TABLE C-2 (Continued)

CSDP/FEIS RISK ANALYSIS
- Accident Scenario Descriptions -
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RECORD NUMBER	ID		SCENARIO
331	SL	E28	Earthquake occurs, UMDA warehouses intact, munitions in one warehouse damaged, fire occurs at warehouse with undamaged munitions.
513	SL	F27	Earthquake occurs, 2 TEAD warehouse damaged; munitions intact; fire occurs at 2 warehouses.
332	SL	F28	Earthquake occurs, UMDA warehouses intact, munitions in one warehouse damaged, fire occurs at two warehouses.
333	SL	G28	Earthquake occurs, UMDA warehouses intact, munitions in two warehouses damaged, no fire occurs.
334	SL	H28	Earthquake occurs, UMDA warehouses intact, munitions in two warehouses damaged, fire occurs at warehouse with damaged munitions.
335	SL	K28	Earthquake occurs, one UMDA warehouse damaged, munitions in one warehouse damaged, fire occurs at warehouse with damaged munitions.
336	SL	L28	Earthquake occurs, one UMDA warehouse damaged, munitions in one warehouse damaged, fire occurs at two warehouses.
337	SL	M28	Earthquake occurs, one UMDA warehouse damaged, munitions in two warehouses damaged, no fire occurs.
338	SL	N27	Earthquake occurs, one UMDA warehouse damaged, munitions in two warehouses damaged, fire occurs in warehouse with damaged munitions.
339	SL	O28	Earthquake occurs, one UMDA warehouse damaged, munitions in two warehouses damaged, fire occurs at two warehouses.
340	SL	P28	Earthquake occurs, two UMDA warehouses damaged, munitions in two warehouses damaged, no fire occurs.
341	SL	Q28	Earthquake occurs, two UMDA warehouses damaged, munitions in two warehouses damaged, fire occurs at both warehouses.
** SR			
14	SR	001	Large aircraft direct crash onto transportation containers in holding area; no fire.
15	SR	002	Large aircraft direct crash onto transportation containers in holding area; fire not contained.
16	SR	003	Large aircraft direct crash onto transportation containers in holding area; fire contained.
17	SR	004	Small aircraft direct crash onto transportation containers in holding area; no fire.
18	SR	005	Small aircraft direct crash onto transportation containers in holding area; fire not contained.
19	SR	006	Small aircraft direct crash onto transportation containers in holding area; fire contained.
20	SR	007	Tornado-generated missiles strike munitions in transportation containers in holding area; no detonation.
21	SR	008	Tornado-generated missiles strike munitions in transportation containers in holding area; detonation occurs.
279	SR	008	Tornado-generated missile penetrates containers; detonation occur.
22	SR	009	Meteorite strikes munitions in transportation containers in holding area; fire occurs; detonation (if burstered).
** SW			
23	SW	001	Large aircraft direct crash onto transportation containers in holding area; no fire.
24	SW	002	Large aircraft direct crash onto transportation containers in holding area; fire not contained.
25	SW	003	Large aircraft direct crash onto transportation containers in holding area; fire contained.
26	SW	004	Small aircraft direct crash onto transportation containers in holding area; no fire.
27	SW	005	Small aircraft direct crash onto transportation containers in holding area; fire not contained.
28	SW	006	Small aircraft direct crash onto transportation containers in holding area; fire contained.
277	SW	007	Tornado-generated missile penetrates vault
29	SW	009	Meteorite strikes munitions in transportation containers in holding area; fire occurs.
278	SW	009	Meteorite strikes vault
30	SW	010	Large aircraft direct crash onto a flotilla of lighers; no fire.
31	SW	011	Large aircraft direct crash onto a flotilla of lighers; fire not contained.
32	SW	012	Large aircraft direct crash onto a flotilla of lighers; fire contained.
33	SW	013	Small aircraft direct crash onto a flotilla of lighers; no fire.
34	SW	014	Small aircraft direct crash onto a flotilla of lighers; fire not contained.
35	SW	015	Small aircraft direct crash onto a flotilla of lighers; fire contained.

TABLE C-2 (Continued)
CSDP/FEIS RISK ANALYSIS
- Accident Scenario Descriptions -
(Data File: MASTER4.DBF)
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RECORD NUMBER	ID		SCENARIO
36	SW	016	Large aircraft direct crash onto LASH vessel (at rest); no fire.
37	SW	017	Large aircraft direct crash onto LASH vessel (at rest); fire not contained.
38	SW	018	Large aircraft direct crash onto LASH vessel (at rest); fire contained.
39	SW	019	Small aircraft direct crash onto LASH vessel (at rest); no fire.
40	SW	020	Small aircraft direct crash onto LASH vessel (at rest); fire not contained.
41	SW	021	Small aircraft direct crash onto LASH vessel (at rest); fire contained.
** VA			
150	VA	001	A munitions vehicle collision/overturn occurs and crush forces fail the agent containment.
151	VA	002	A munitions vehicle collision/overturn occurs and impact forces fail the agent containment.
152	VA	003	A munitions vehicle collision/overturn occurs and puncture forces fail the agent containment.
153	VA	004	Detonation of burstered munitions occurs by either 1) fire-only accident, 2) mechanical force and fire, 3) truck collision/overturn impact - induced rocket propellant ignition, or 4) truck collision/overturn - induced undue force detonation.
251	VA	005	A munitions vehicle accident with fire occurs, causing non-burstered munitions to fail.
154	VA	006	An aircraft crashes on a munitions vehicle. No fire occurs; impact forces fail the agent containment.
155	VA	007	An aircraft crashes on a munitions vehicle. Fire occurs but impact forces fail the agent containment.
156	VA	009	A severe earthquake occurs, causing a munitions vehicle accident and crush forces fail the agent containment.
157	VA	010	A severe earthquake occurs, causing a munitions vehicle accident and impact forces forces fail the agent containment.
158	VA	011	A severe earthquake occurs, causing a munitions vehicle accident and puncture forces forces fail the agent containment.
159	VA	012	A severe earthquake occurs, causing a munitions vehicle accident and fire detonates burstered munitions.
250	VA	013	A severe earthquake occurs, causing a munitions vehicle accident and fire fails nonburstered munitions.
160	VA	014	A tornado occurs, generating under mechanical forces which cause detonation of burstered munitions.
161	VA	015	A earthquake or tornado occurs, generating under mechanical forces which cause detonation of burstered munitions.
** VB			
466	VB	001	A munitions vehicle collision/overturn occurs and crush forces fail the agent containment.
467	VB	002	A munitions vehicle collision/overturn occurs and impact forces fail the agent containment.
468	VB	003	A munitions vehicle collision/overturn occurs and puncture forces fail the agent containment.
469	VB	004	Detonation of burstered munitions occurs by either 1) fire-only accident, 2) mechanical force and fire, 3) truck collision/overturn impact - induced rocket propellant ignition, or 4) truck collision/overturn - induced undue force detonation.
470	VB	006	An aircraft crashes on a munitions vehicle. No fire occurs; impact forces fail the agent containment.
471	VB	007	An aircraft crashes on a munitions vehicle. Fire occurs but impact forces fail the agent containment.
472	VB	009	A severe earthquake occurs, causing a munitions vehicle accident and crush forces fail the agent containment.
473	VB	010	A severe earthquake occurs, causing a munitions vehicle accident and impact forces forces fail the agent containment.
474	VB	011	A severe earthquake occurs, causing a munitions vehicle accident and puncture forces forces fail the agent containment.
475	VB	012	A severe earthquake occurs, causing a munitions vehicle accident and fire detonates burstered munitions.
476	VB	014	A tornado occurs, generating under mechanical forces which cause detonation of burstered munitions.
477	VB	015	A earthquake or tornado occurs, generating under mechanical forces which cause detonation of burstered munitions.
** VO			
130	VO	001	A munitions vehicle collision/overturn occurs and crush forces fail the agent containment.
131	VO	003	A munitions vehicle collision/overturn occurs and puncture forces fail the agent containment.
132	VO	004	A munitions vehicle accident with fire occurs, causing detonation of burstered munitions. Ignition of the propellant by

TABLE C-2 (Continued)
CSDP/FEIS RISK ANALYSIS
- Accident Scenario Descriptions -
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RECORD NUMBER	ID		SCENARIO
			a probe could also detonate the burster of a cartridge and the burster of a rocket could be detonated by impact-induced ignition of the rocket propellant.
133	VO	005	A munitions vehicle accident with fire occurs, causing non-burstered munitions to fail.
134	VO	006	An aircraft crashes on a munitions vehicle. No fire occurs; impact forces fail the agent containment.
135	VO	007	An aircraft crashes on a munitions vehicle. Fire occurs; but impact forces fail the agent containment.
136	VO	009	A severe earthquake occurs, causing a munitions vehicle accident and crush forces fail the agent containment.
252	VO	010	A severe earthquake occurs, causing a munitions vehicle accident and impact forces fail the agent containment.
137	VO	011	A severe earthquake occurs, causing a munitions vehicle accident and puncture forces fail the agent containment.
138	VO	012	A severe earthquake occurs, causing a munitions vehicle accident and fire fails detonates burstered munitions.
139	VO	013	A severe earthquake occurs, causing a munitions vehicle accident and fire fails nonburstered munitions.
140	VO	014	A tornado occurs, generating a missile or causing a truck overturn and mechanical forces fail agent containment.
141	VO	015	A truck collision/overturn occurs generating undue mechanical forces which cause detonation of burstered munitions.
** VR			
253	VR	001	A munitions vehicle collision/overturn occurs and crush forces fail the agent containment.
254	VR	002	A munitions vehicle collision/overturn occurs and impact forces fail the agent containment.
162	VR	003	A munitions vehicle collision/overturn occurs and puncture forces fail the agent containment.
163	VR	004	Detonation of burstered munitions occurs by either 1) fire-only accident, 2) mechanical force and fire, 3) truck collision/overturn impact-induced rocket propellant ignition, or 4) truck collision/overturn-induced undue force detonation.
255	VR	005	A munitions vehicle accident with fire occurs, causing nonburstered munitions to fail.
164	VR	006	An aircraft crashes on a munitions vehicle. No fire occurs; impact forces fail the agent containment.
165	VR	007	An aircraft crashes on a munitions vehicle. Fire occurs; but impact forces fail the agent containment.
256	VR	009	A severe earthquake occurs, causing a munitions vehicle accident and crush forces fail the agent containment.
257	VR	010	A severe earthquake occurs, causing a munitions vehicle accident and impact forces fail the agent containment.
166	VR	011	A severe earthquake occurs, causing a munitions vehicle accident and puncture forces fail the agent agent containment.
167	VR	012	A severe earthquake occurs, causing a munitions vehicle accident and fire detonates burstered munitions.
168	VR	013	A severe earthquake occurs, causing a munitions vehicle accident and fire fails nonburstered munitions.
169	VR	014	A tornado occurs, generating a missile or causing a truck overturn, and mechanical forces fail agent containment.
170	VR	015	An earthquake or tornado occurs, generating undue mechanical force s which cause detonation of burstered munitions.
** VW			
506	VW	001	A munitions vehicle collision/overturn occurs and crush forces fail the agent containment.
507	VW	002	A munitions vehicle collision/overturn occurs and impact forces fail the agent containment.
142	VW	003	A munitions vehicle collision/overturn occurs and puncture forces fail the agent containment.
143	VW	005	A munitions vehicle accident with fire occurs, causing nonburstered munitions to fail.
144	VW	006	An aircraft crashes on a munitions vehicle. No fire occurs; impact forces fail the agent containment.
145	VW	007	An aircraft crashes on a munitions vehicle. Fire occurs; but impact forces fail the agent containment.
146	VW	009	A severe earthquake occurs, causing a munitions vehicle accident and crush forces fail the agent containment.
508	VW	009	A severe earthquake occurs, causing a munitions vehicle accident and crush forces fail the agent containment.
147	VW	010	A severe earthquake occurs, causing a munitions vehicle accident and impact forces fail the agent containment.
509	VW	010	A severe earthquake occurs, causing a munitions vehicle accident and impact forces fail the agent containment.
148	VW	011	A severe earthquake occurs, causing a munitions vehicle accident and puncture forces fail the agent containment.
510	VW	013	A severe earthquake occurs, causing a munitions vehicle accident and fire fails nonburstered munitions.
149	VW	014	A tornado occurs, generating a missile or causing a truck overturn, and mechanical forces fail agent containment.

TABLE C-2 (Continued)
CSDP/FEIS RISK ANALYSIS
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RECORD NUMBER	ID		SCENARIO
** WB			
511	WB	001	A collision occurs and crush forces fail agent containment.
44	WB	002	A collision occurs and crush forces fail agent containment. Sinking also occurs.
48	WB	003	A collision occurs and crush forces fail agent containment. A fire breaks out.
52	WB	004	A collision occurs and crush forces fail agent containment. A fire breaks out and sinking occurs.
56	WB	005	A ramming occurs and crush forces fail agent containment.
60	WB	006	A ramming occurs and crush forces fail agent containment. Sinking also occurs.
259	WB	007	A ramming accident occurs and crush forces fail agent containment. A fire breaks out.
67	WB	008	A ramming occurs and crush forces fail agent containment. A fire breaks out and sinking occurs.
260	WB	009	A grounding accident occurs and crush forces fail agent containment.
74	WB	010	A grounding accident occurs and crush forces fail agent containment. Sinking also occurs.
261	WB	011	A grounding accident occurs and crush forces fail agent containment. A fire breaks out.
81	WB	012	A grounding accident occurs and crush forces fail agent containment. A fire breaks out and sinking occurs.
262	WB	013	Structural damage due to heavy weather occurs. Crush forces fail agent containment.
88	WB	014	Structural damage due to heavy weather occurs. Crush forces fail agent containment. Sinking also occurs.
263	WB	015	Structural damage due to heavy weather occurs. Crush forces fail agent containment. A fire breaks out.
95	WB	016	Structural damage due to heavy weather occurs. Crush forces fail agent containment. A fire breaks out and sinking occurs.
264	WB	017	Spontaneous fire occurs.
265	WB	018	Spontaneous fire occurs. Sinking also occurs.
105	WB	019	Collision accident occurs with no immediate release. Sinking also occurs.
109	WB	020	Ramming accident occurs with no immediate release. Sinking also occurs.
112	WB	021	Grounding accident occurs with no immediate release. Sinking also occurs.
116	WB	022	Structural damage due to heavy weather occurs with no immediate release. Sinking also occurs.
245	WB	023	Aircraft crashes into marine vessel.
** WC			
258	WC	001	A collision occurs and crush forces fail agent containment.
46	WC	002	A collision occurs and crush forces fail agent containment. Sinking also occurs.
50	WC	003	A collision occurs and crush forces fail agent containment. A fire breaks out.
54	WC	004	A collision occurs and crush forces fail agent containment. A fire breaks out and sinking occurs.
58	WC	005	A ramming occurs and crush forces fail agent containment.
62	WC	006	A ramming occurs and crush forces fail agent containment. Sinking also occurs.
65	WC	007	A ramming occurs and crush forces fail agent containment. A fire breaks out.
69	WC	008	A ramming occurs and crush forces fail agent containment. A fire breaks out and sinking occurs.
72	WC	009	A grounding accident occurs and crush forces fail agent containment.
76	WC	010	A grounding accident occurs and crush forces fail agent containment. Sinking also occurs.
79	WC	011	A grounding accident occurs and crush forces fail agent containment. A fire breaks out.
83	WC	012	A grounding accident occurs and crush forces fail agent containment. A fire breaks out and sinking occurs.
86	WC	013	Structural damage due to heavy weather occurs. Crush forces fail agent containment.
90	WC	014	Structural damage due to heavy weather occurs. Crush forces fail agent containment. Sinking also occurs.
93	WC	015	Structural damage due to heavy weather occurs. Crush forces fail agent containment. A fire breaks out.
97	WC	016	Structural damage due to heavy weather occurs. Crush forces fail agent containment. A fire breaks out and sinking occurs.
100	WC	017	Spontaneous fire occurs.

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CSDP/FEIS RISK ANALYSIS
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RECORD NUMBER	ID		SCENARIO
103	WC	018	Spontaneous fire occurs. Sinking also occurs.
107	WC	019	Collision accident occurs with no immediate release. Sinking also occurs.
111	WC	020	Ramming accident occurs with no immediate release. Sinking also occurs.
114	WC	021	Grounding accident occurs with no immediate release. Sinking also occurs.
118	WC	022	Structural damage due to heavy weather occurs with no immediate release. Sinking also occurs.
247	WC	023	Aircraft crashes into marine vessel.
** WI			
42	WI	001	A collision occurs and crush forces fail agent containment.
45	WI	002	A collision occurs and crush forces fail agent containment. Sinking also occurs.
49	WI	003	A collision occurs and crush forces fail agent containment. A fire breaks out.
53	WI	004	A collision occurs and crush forces fail agent containment. A fire breaks out and sinking occurs.
57	WI	005	A ramming occurs and crush forces fail agent containment.
61	WI	006	A ramming occurs and crush forces fail agent containment. Sinking also occurs.
64	WI	007	A ramming occurs and crush forces fail agent containment. A fire breaks out.
68	WI	008	A ramming occurs and crush forces fail agent containment. A fire breaks out and sinking occurs.
71	WI	009	A grounding accident occurs and crush forces fail agent containment.
75	WI	010	A grounding accident occurs and crush forces fail agent containment. Sinking also occurs.
78	WI	011	A grounding accident occurs and crush forces fail agent containment. A fire breaks out.
82	WI	012	A grounding accident occurs and crush forces fail agent containment. A fire breaks out and sinking occurs.
85	WI	013	Structural damage due to heavy weather occurs. Crush forces fail agent containment.
89	WI	014	Structural damage due to heavy weather occurs. Crush forces fail agent containment. Sinking also occurs.
92	WI	015	Structural damage due to heavy weather occurs. Crush forces fail agent containment. A fire breaks out.
96	WI	016	Structural damage due to heavy weather occurs. Crush forces fail agent containment. A fire breaks out and sinking occurs.
99	WI	017	Spontaneous fire occurs.
102	WI	018	Spontaneous fire occurs. Sinking also occurs.
106	WI	019	Collision accident occurs with no immediate release. Sinking also occurs.
110	WI	020	Ramming accident occurs with no immediate release. Sinking also occurs.
113	WI	021	Grounding accident occurs with no immediate release. Sinking also occurs.
117	WI	022	Structural damage due to heavy weather occurs with no immediate release. Sinking also occurs.
246	WI	023	Aircraft crashes into marine vessel.
** WS			
43	WS	001	A collision occurs and crush forces fail agent containment.
47	WS	002	A collision occurs and crush forces fail agent containment. Sinking also occurs.
51	WS	003	A collision occurs and crush forces fail agent containment. A fire breaks out.
55	WS	004	A collision occurs and crush forces fail agent containment. A fire breaks out and sinking occurs.
59	WS	005	A ramming occurs and crush forces fail agent containment.
63	WS	006	A ramming occurs and crush forces fail agent containment. Sinking also occurs.
66	WS	007	A ramming occurs and crush forces fail agent containment. A fire breaks out.
70	WS	008	A ramming occurs and crush forces fail agent containment. A fire breaks out and sinking occurs.
73	WS	009	A grounding accident occurs and crush forces fail agent containment.
77	WS	010	A grounding accident occurs and crush forces fail agent containment. Sinking also occurs.
80	WS	011	A grounding accident occurs and crush forces fail agent containment. A fire breaks out.

TABLE C-2 (Concluded)
CSDP/FEIS RISK ANALYSIS
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RECORD NUMBER	ID		SCENARIO
84	WS	012	A grounding accident occurs and crush forces fail agent containment. A fire breaks out and sinking occurs.
87	WS	013	Structural damage due to heavy weather occurs. Crush forces fail agent containment.
91	WS	014	Structural damage due to heavy weather occurs. Crush forces fail agent containment. Sinking also occurs.
94	WS	015	Structural damage due to heavy weather occurs. Crush forces fail agent containment. A fire breaks out.
98	WS	016	Structural damage due to heavy weather occurs. Crush forces fail agent containment. A fire breaks out and sinking occurs.
101	WS	017	Spontaneous fire occurs.
104	WS	018	Spontaneous fire occurs. Sinking also occurs.
108	WS	019	Collision accident occurs with no immediate release. Sinking also occurs.
115	WS	021	Grounding accident occurs with no immediate release. Sinking also occurs.
119	WS	022	Structural damage due to heavy weather occurs with no immediate release. Sinking also occurs.
248	WS	023	Aircraft crashes into marine vessel.

scenario could be the basis for as many as fourteen separate accidents, each one representing the probability and release characteristics of one of the applicable munition-agent combinations.

C.4 Fatality Data

The fatality data provided by the Oak Ridge National Laboratory (ORNL) have been assembled into dBASEIII format as presented in Table C-3. Table C-3 may be interpreted with the aid of the following definitions:

- The first column, **LOCATION or DISPOSAL ALTERNATIVE**, refers to where and for which disposal alternatives the predicted fatalities are presumed to occur; the entries signify the following:
  - **SYT**: about one of the eight storage/disposal sites; applies to all disposal alternatives.
  - **RAR**: along one of the rail corridors for the regional disposal alternative; the table entries (potential fatalities) for this and the other transportation corridors are listed under the column heading signifying the site from which the stockpile responsible for the agent release originated. (e.g., fatality estimates for the transportation corridor from Lexington-Blue Grass Army Depot to Anniston Army Depot, the regional disposal site for Lexington-Blue Grass, would appear under the column heading, L, representing Lexington-Blue Grass.)
  - **RAN**: along one of the rail corridors for the national disposal alternative.
  - **AIR**: along one of the air corridors for the air disposal alternatives.
  - **WTR**: along the water transportation corridor.

- The second column, **WIND DIRECTION & POPULATION DISTRIBUTION**, indicates the demographic assumptions for which the fatality estimates apply:
  - **AV**: signifies a uniform population density and wind rose;
  - **MX**: signifies a maximum population density (based on 1980 U.S. Census data/maps) and the worst wind direction (the one that yields maximum fatalities).

- The third column, **'NO-DEATHS' HAZARD DISTANCE**, specifies the downwind distance, in kilometers, from the site center or the transportation corridor, as appropriate, to the 'no-deaths' dosage boundary.

TABLE C-3

ORNL FATALITY ESTIMATION DATA
(AS USED IN MITRE RISK ANALYSIS MODEL)

LOCATION OR DISPOSAL ALTERNATIVE	WIND DIRECTION & POPULATION DISTRIBUTION (AV=AVG,MX=MAX)	'NO-DEATHS' HAZARD DISTANCE (km)	WEATHER CONDITIONS (ML=MOST LIKELY WC=WORST CASE)	STOCKPILE SITES: ANAD	APG	LBAD	NAAP	PBA	PUDA	TEAD	UMDA
SYT	AV	0.1	WC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.2	WC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.5	WC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		1.0	WC	0.01	1.26	0.00	0.10	0.09	0.01	0.00	0.00
		2.0	WC	0.07	2.76	0.06	0.37	0.30	0.02	0.01	0.02
		5.0	WC	0.68	24.38	2.60	2.16	2.42	0.15	0.07	0.36
		10.0	WC	21.28	89.06	49.52	9.29	13.81	0.69	0.26	6.50
		20.0	WC	224.28	372.49	132.70	35.09	103.18	8.87	1.03	52.11
		50.0	WC	1072.78	4567.70	777.27	504.77	495.88	335.52	51.83	179.59
		100.0	WC	3104.88	14808.48	2413.14	2245.35	2292.73	1539.60	2295.76	807.48
		200.0	WC	9026.63	44048.01	7101.14	7310.53	6598.40	3165.96	4858.19	2563.90
		500.0	WC	26410.11	116372.37	15981.66	19803.89	14060.99	8634.39	16772.80	5459.91
		1000.0	WC	38627.91	170208.33	23375.07	28965.53	20565.86	12628.82	24532.20	7985.76
SYT	MX	0.1	WC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.2	WC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.5	WC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		1.0	WC	0.19	43.67	0.16	1.15	1.33	0.07	0.03	0.04
		2.0	WC	0.41	83.25	0.60	2.66	3.16	0.11	0.05	0.26
		5.0	WC	2.85	275.88	18.93	7.41	20.08	0.72	0.17	1.80
		10.0	WC	57.27	834.65	468.74	16.08	38.89	2.85	0.42	18.45
		20.0	WC	1439.30	2294.43	1801.11	141.45	925.70	30.26	1.75	652.17
		50.0	WC	4986.01	42006.78	6570.40	2541.25	5359.40	6301.77	1072.28	2524.63
		100.0	WC	10730.73	120185.14	18640.33	17799.09	15659.83	16472.78	19811.64	9805.66
		200.0	WC	70513.16	343222.33	54119.30	45548.24	40078.22	41630.01	58626.23	23792.57
		500.0	WC	244118.12	793686.56	107246.08	89456.04	106272.32	141613.20	218803.49	49811.72
		1000.0	WC	328832.93	1159756.21	138749.37	96302.03	150360.44	197087.03	311510.94	57108.18
SYT	AV	0.1	ML	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.2	ML	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.5	ML	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		1.0	ML	0.03	2.40	0.01	0.22	0.21	0.01	0.01	0.01
		2.0	ML	0.15	6.26	0.13	0.86	0.66	0.05	0.03	0.05
		5.0	ML	1.72	54.36	6.66	4.94	5.55	0.34	0.16	0.92
		10.0	ML	53.39	218.97	111.73	22.47	31.80	1.61	0.59	15.43
		20.0	ML	508.49	908.85	334.98	82.34	267.51	20.62	2.42	120.30
		50.0	ML	2392.55	10186.39	1900.95	1229.01	1435.40	674.47	116.38	428.01
		100.0	ML	7482.58	38714.69	5349.92	5283.04	4697.39	3671.98	4722.17	1621.43
		200.0	ML	19624.80	91602.05	14634.77	14735.02	13536.42	7993.60	15889.02	5188.97
		500.0	ML	49839.16	219609.11	30159.39	37372.41	26534.84	16294.17	31652.36	10303.52

TABLE C-3

ORNL FATALITY ESTIMATION DATA
(AS USED IN MITRE RISK ANALYSIS MODEL) (CONTINUED)

LOCATION OR DISPOSAL ALTERNATIVE	WIND DIRECTION & POPULATION DISTRIBUTION (AV=AVG,MX=MAX)	'NO-DEATHS' HAZARD DISTANCE (km)	WEATHER CONDITIONS (ML=MOST LIKELY WC=WORST CASE)	STOCKPILE SITES: ANAD	APG	LBAD	NAAP	PBA	PUDA	TEAD	UMDA
		1000.0	ML	68544.15	302029.94	41478.41	51398.53	36493.55	22409.48	43531.71	14170.51
SYT	MX	0.1	ML	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.2	ML	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.5	ML	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		1.0	ML	0.19	67.78	0.19	1.92	1.61	0.07	0.04	0.07
		2.0	ML	0.63	96.96	0.83	3.46	5.23	0.16	0.08	0.29
		5.0	ML	5.82	538.65	29.38	9.19	24.90	1.21	0.26	3.21
		10.0	ML	151.19	1542.20	1082.52	41.80	94.53	5.86	0.79	41.32
		20.0	ML	2625.48	4774.68	3489.80	246.23	2013.65	78.26	4.17	1393.31
		50.0	ML	11024.49	92469.66	10698.87	5719.43	12383.57	14382.04	2041.05	5282.97
		100.0	ML	23640.04	264664.94	37086.09	26162.86	32351.10	39590.77	49396.74	16988.73
		200.0	ML	120269.69	574631.61	109314.72	69656.87	100390.74	90462.14	136485.60	49129.85
		500.0	ML	367666.28	1369607.87	160460.48	100544.07	184481.02	213693.58	362104.98	62812.51
		1000.0	ML	441585.83	1727481.76	196555.55	109392.64	233712.71	223756.79	451665.32	87502.88
RAR	AV	0.1	WC	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
		0.2	WC	0.00	0.03	0.01	0.01	0.02	0.01	0.00	0.00
		0.5	WC	0.00	0.23	0.09	0.09	0.10	0.08	0.00	0.02
		1.0	WC	0.00	0.91	0.37	0.36	0.39	0.32	0.00	0.06
		2.0	WC	0.00	3.55	1.49	1.39	1.51	1.31	0.00	0.25
		5.0	WC	0.00	18.71	8.04	7.50	7.75	11.23	0.00	1.38
		10.0	WC	0.00	59.10	26.56	24.00	24.68	43.18	0.00	4.51
		20.0	WC	0.00	178.52	92.17	76.01	80.63	124.39	0.00	15.16
		50.0	WC	0.00	885.15	511.58	376.05	423.03	393.94	0.00	122.79
		100.0	WC	0.00	3634.64	2173.36	1463.68	1837.59	979.12	0.00	518.77
		200.0	WC	0.00	11373.00	6130.92	3903.03	5538.16	2325.94	0.00	1575.10
		500.0	WC	0.00	31728.77	16459.84	10681.98	15856.40	5387.24	0.00	4145.36
		1000.0	WC	0.00	46407.08	24074.46	15623.66	23191.86	7879.47	0.00	6063.07
RAR	MX	0.1	WC	0.00	0.00	0.00	117.64	0.44	0.01	0.00	0.01
		0.2	WC	0.00	0.02	0.00	117.64	0.44	0.02	0.00	5.05
		0.5	WC	0.00	121.36	121.36	352.92	121.36	27.33	0.00	15.16
		1.0	WC	0.00	413.51	413.51	497.76	413.51	99.76	0.00	20.79
		2.0	WC	0.00	697.56	431.05	1263.04	431.05	211.74	0.00	36.32
		5.0	WC	0.00	3440.65	708.84	1619.45	708.84	893.50	0.00	176.95
		10.0	WC	0.00	7645.14	893.21	2079.92	893.21	2272.02	0.00	436.03
		20.0	WC	0.00	19959.93	1801.11	2988.52	1695.08	6281.94	0.00	1007.95
		50.0	WC	0.00	48472.42	6570.40	5422.48	5359.40	23370.27	0.00	2524.63
		100.0	WC	0.00	120185.14	18640.33	17799.09	15659.83	73116.38	0.00	19811.64
		200.0	WC	0.00	343222.33	70513.16	70513.16	70513.16	120769.73	0.00	58626.23

TABLE C-3
ORNL FATALITY ESTIMATION DATA
(AS USED IN MITRE RISK ANALYSIS MODEL) (CONTINUED)

LOCATION OR DISPOSAL ALTERNATIVE	WIND DIRECTION & POPULATION DISTRIBUTION (AV=AVG,MX=MAX)	'NO-DEATHS' HAZARD DISTANCE (km)	WEATHER CONDITIONS (ML=MOST LIKELY WC=WORST CASE)	STOCKPILE SITES: ANAD	APG	LBAD	NAAP	PBA	PUDA	TEAD	UMDA
		500.0	WC	0.00	793686.56	244118.12	244118.12	244118.12	228192.46	0.00	218803.49
		1000.0	WC	0.00	1159756.21	328832.93	328832.93	328832.93	311510.94	0.00	311510.94
RAR	AV	0.1	ML	0.00	0.02	0.01	0.01	0.01	0.01	0.00	0.00
		0.2	ML	0.00	0.08	0.03	0.03	0.04	0.03	0.00	0.01
		0.5	ML	0.00	0.52	0.21	0.21	0.22	0.18	0.00	0.04
		1.0	ML	0.00	2.07	0.85	0.82	0.88	0.74	0.00	0.15
		2.0	ML	0.00	8.09	3.42	3.19	3.45	3.09	0.00	0.58
		5.0	ML	0.00	42.67	18.34	17.10	17.63	25.87	0.00	3.12
		10.0	ML	0.00	132.75	60.37	54.39	55.67	99.90	0.00	10.20
		20.0	ML	0.00	400.91	208.34	171.36	182.01	279.04	0.00	34.58
		50.0	ML	0.00	2004.93	1183.99	848.50	965.44	845.43	0.00	285.66
		100.0	ML	0.00	8367.48	4924.46	3314.72	4266.07	2089.67	0.00	1211.70
		200.0	ML	0.00	25240.97	13830.24	8890.34	12404.12	4959.53	0.00	3446.85
		500.0	ML	0.00	59876.14	31061.77	20158.22	29922.99	10166.38	0.00	7822.80
		1000.0	ML	0.00	82348.07	42719.46	27723.74	41153.30	13981.90	0.00	10758.75
RAR	MX	0.1	ML	0.00	0.00	0.00	117.64	0.44	0.01	0.00	0.01
		0.2	ML	0.00	0.97	0.00	352.92	0.44	0.02	0.00	5.05
		0.5	ML	0.00	121.36	121.36	352.92	121.36	27.33	0.00	15.16
		1.0	ML	0.00	413.51	413.51	497.76	413.51	101.02	0.00	20.79
		2.0	ML	0.00	801.10	433.31	1372.61	433.31	306.46	0.00	53.55
		5.0	ML	0.00	4760.80	896.96	1856.88	896.96	1147.73	0.00	340.15
		10.0	ML	0.00	13947.83	1668.98	3507.96	1668.98	4140.81	0.00	832.44
		20.0	ML	0.00	37172.73	3489.80	5225.55	3143.93	13377.48	0.00	1740.21
		50.0	ML	0.00	92469.66	11024.49	11024.49	12383.57	50063.23	0.00	5282.97
		100.0	ML	0.00	264664.94	37086.09	26162.86	32351.10	129716.07	0.00	49396.74
		200.0	ML	0.00	643588.81	120269.69	120269.69	120269.69	224093.94	0.00	136485.60
		500.0	ML	0.00	1369607.87	367666.28	367666.28	367666.28	362104.98	0.00	362104.98
		1000.0	ML	0.00	1727481.76	441585.83	441585.83	441585.83	451665.32	0.00	451665.32
RAM	AV	0.1	WC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.2	WC	0.01	0.03	0.01	0.01	0.01	0.01	0.00	0.00
		0.5	WC	0.09	0.18	0.08	0.09	0.07	0.08	0.00	0.02
		1.0	WC	0.36	0.71	0.33	0.37	0.28	0.32	0.00	0.06
		2.0	WC	1.39	2.75	1.31	1.42	1.09	1.31	0.00	0.25
		5.0	WC	7.50	14.82	7.31	7.72	5.73	11.23	0.00	1.38
		10.0	WC	24.00	47.62	24.10	24.47	18.35	43.18	0.00	4.51
		20.0	WC	76.01	141.49	76.01	73.09	56.26	124.39	0.00	15.16
		50.0	WC	376.05	717.50	371.25	337.96	239.97	393.94	0.00	122.79
		100.0	WC	1463.68	3265.73	1566.82	1394.99	1018.42	979.12	0.00	518.77

TABLE C-3
ORNL FATALITY ESTIMATION DATA
(AS USED IN MITRE RISK ANALYSIS MODEL) (CONTINUED)

LOCATION OR DISPOSAL ALTERNATIVE	WIND DIRECTION & POPULATION DISTRIBUTION (AV=AVG,MX=MAX)	'NO-DEATHS' HAZARD DISTANCE (km)	WEATHER CONDITIONS (ML=MOST LIKELY WC=WORST CASE)	STOCKPILE SITES: ANAD	APG	LBAD	NAAP	PBA	PUDA	TEAD	UMDA
		200.0	WC	3903.03	9698.52	4259.38	3763.90	2857.04	2325.94	0.00	1575.10
		500.0	WC	10681.98	26882.93	11733.59	10739.07	8038.20	5387.24	0.00	4145.36
		1000.0	WC	15623.66	39319.45	17161.76	15707.16	11756.82	7879.47	0.00	6063.07
RAN	MX	0.1	WC	0.01	0.01	0.01	117.64	0.44	0.01	0.00	0.01
		0.2	WC	0.01	0.02	0.01	117.64	0.44	0.02	0.00	5.05
		0.5	WC	121.36	83.96	27.33	352.92	27.33	27.33	0.00	15.16
		1.0	WC	413.51	150.34	99.76	497.76	99.76	99.76	0.00	20.79
		2.0	WC	431.05	697.56	211.74	1263.04	211.74	211.74	0.00	36.32
		5.0	WC	893.50	3440.65	893.50	1619.45	893.50	893.50	0.00	176.95
		10.0	WC	2272.02	7645.14	2272.02	2272.02	2272.02	2272.02	0.00	436.03
		20.0	WC	6281.94	19959.93	6281.94	6281.94	6281.94	6281.94	0.00	1007.95
		50.0	WC	23370.27	48472.42	23370.27	23370.27	23370.27	23370.27	0.00	2524.63
		100.0	WC	73116.38	120185.14	73116.38	73116.38	73116.38	73116.38	0.00	19811.64
		200.0	WC	120769.73	343222.33	120769.73	120769.73	120769.73	120769.73	0.00	58626.23
		500.0	WC	244118.12	793686.56	228192.46	228192.46	228192.46	228192.46	0.00	218803.49
		1000.0	WC	328832.93	1159756.21	311510.94	311510.94	311510.94	311510.94	0.00	311510.94
RAN	AV	0.1	ML	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.00
		0.2	ML	0.03	0.06	0.03	0.03	0.03	0.03	0.00	0.01
		0.5	ML	0.21	0.40	0.19	0.21	0.17	0.18	0.00	0.04
		1.0	ML	0.82	1.60	0.76	0.84	0.65	0.74	0.00	0.15
		2.0	ML	3.19	6.30	3.01	3.29	2.49	3.09	0.00	0.58
		5.0	ML	17.10	33.90	16.73	17.62	13.09	25.87	0.00	3.12
		10.0	ML	54.39	107.09	54.72	55.26	41.34	99.90	0.00	10.20
		20.0	ML	171.36	317.87	171.52	164.03	125.45	279.04	0.00	34.58
		50.0	ML	848.50	1620.48	844.83	756.16	540.35	845.43	0.00	285.66
		100.0	ML	3314.72	7417.51	3546.07	3182.71	2320.90	2089.67	0.00	1211.70
		200.0	ML	8890.34	22279.52	9784.12	8643.42	6471.75	4959.53	0.00	3446.85
		500.0	ML	20158.22	50731.42	22142.74	20265.96	15169.08	10166.38	0.00	7822.80
		1000.0	ML	27723.74	69771.27	30453.06	27871.91	20862.14	13981.90	0.00	10758.75
RAN	MX	0.1	ML	0.01	0.01	0.01	117.64	0.44	0.01	0.00	0.01
		0.2	ML	0.01	0.97	0.01	352.92	0.44	0.02	0.00	5.05
		0.5	ML	121.36	83.96	27.33	352.92	27.33	27.33	0.00	15.16
		1.0	ML	413.51	410.48	101.02	497.76	101.02	101.02	0.00	20.79
		2.0	ML	433.31	801.10	306.46	1372.61	306.46	306.46	0.00	53.55
		5.0	ML	1147.73	4760.80	1147.73	1856.88	1147.73	1147.73	0.00	340.15
		10.0	ML	4140.81	13947.83	4140.81	4140.81	4140.81	4140.81	0.00	832.44
		20.0	ML	13377.48	37172.73	13377.48	13377.48	13377.48	13377.48	0.00	1740.21
		50.0	ML	50063.23	92469.66	50063.23	50063.23	50063.23	50063.23	0.00	5282.97

TABLE C-3
ORNL FATALITY ESTIMATION DATA
(AS USED IN MITRE RISK ANALYSIS MODEL) (CONTINUED)

LOCATION OR DISPOSAL ALTERNATIVE	WIND DIRECTION & POPULATION DISTRIBUTION (AV=AVG,MX=MAX)	'NO-DEATHS' HAZARD DISTANCE (km)	WEATHER CONDITIONS (ML=MOST LIKELY WC=WORST CASE)	STOCKPILE SITES: ANAD	APG	LBAD	NAAP	PBA	PUDA	TEAD	UMDA
		100.0	ML	129716.07	264664.94	129716.07	129716.07	129716.07	129716.07	0.00	49396.74
		200.0	ML	224093.94	643588.81	224093.94	224093.94	224093.94	224093.94	0.00	136485.60
		500.0	ML	367666.28	1369607.87	362104.98	362104.98	362104.98	362104.98	0.00	362104.98
		1000.0	ML	451665.32	1727481.76	451665.32	451665.32	451665.32	451665.32	0.00	451665.32
AIR	AV	0.1	WC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.2	WC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.5	WC	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00
		1.0	WC	0.00	0.07	0.04	0.00	0.00	0.00	0.00	0.00
		2.0	WC	0.00	0.27	0.18	0.00	0.00	0.00	0.00	0.00
		5.0	WC	0.00	1.79	1.10	0.00	0.00	0.00	0.00	0.00
		10.0	WC	0.00	7.97	4.97	0.00	0.00	0.00	0.00	0.00
		20.0	WC	0.00	37.04	22.77	0.00	0.00	0.00	0.00	0.00
		50.0	WC	0.00	339.95	196.38	0.00	0.00	0.00	0.00	0.00
		100.0	WC	0.00	1997.32	1204.39	0.00	0.00	0.00	0.00	0.00
		200.0	WC	0.00	6225.71	4087.71	0.00	0.00	0.00	0.00	0.00
		500.0	WC	0.00	18180.02	11993.03	0.00	0.00	0.00	0.00	0.00
		1000.0	WC	0.00	26590.42	17541.22	0.00	0.00	0.00	0.00	0.00
AIR	MX	0.1	WC	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
		0.2	WC	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00
		0.5	WC	0.00	83.96	27.33	0.00	0.00	0.00	0.00	0.00
		1.0	WC	0.00	150.34	99.76	0.00	0.00	0.00	0.00	0.00
		2.0	WC	0.00	697.56	211.74	0.00	0.00	0.00	0.00	0.00
		5.0	WC	0.00	3440.65	893.53	0.00	0.00	0.00	0.00	0.00
		10.0	WC	0.00	7645.14	2272.02	0.00	0.00	0.00	0.00	0.00
		20.0	WC	0.00	19959.93	6281.94	0.00	0.00	0.00	0.00	0.00
		50.0	WC	0.00	48472.42	23370.27	0.00	0.00	0.00	0.00	0.00
		100.0	WC	0.00	120185.14	73116.38	0.00	0.00	0.00	0.00	0.00
		200.0	WC	0.00	343222.33	120769.73	0.00	0.00	0.00	0.00	0.00
		500.0	WC	0.00	793686.56	228192.46	0.00	0.00	0.00	0.00	0.00
		1000.0	WC	0.00	1159756.21	311510.94	0.00	0.00	0.00	0.00	0.00
AIR	AV	0.1	ML	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.2	ML	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
		0.5	ML	0.00	0.04	0.03	0.00	0.00	0.00	0.00	0.00
		1.0	ML	0.00	0.15	0.10	0.00	0.00	0.00	0.00	0.00
		2.0	ML	0.00	0.61	0.41	0.00	0.00	0.00	0.00	0.00
		5.0	ML	0.00	4.17	2.57	0.00	0.00	0.00	0.00	0.00
		10.0	ML	0.00	18.52	11.56	0.00	0.00	0.00	0.00	0.00
		20.0	ML	0.00	86.21	53.08	0.00	0.00	0.00	0.00	0.00

TABLE C-3

ORNL FATALITY ESTIMATION DATA
(AS USED IN MITRE RISK ANALYSIS MODEL) (CONTINUED)

LOCATION OR DISPOSAL ALTERNATIVE	WIND DIRECTION & POPULATION DISTRIBUTION (AV=AVG,MX=MAX)	'NO-DEATHS' HAZARD DISTANCE (km)	WEATHER CONDITIONS (ML=MOST LIKELY WC=WORST CASE)	STOCKPILE SITES: ANAD	APG	LBAD	NAAP	PBA	PUDA	TEAD	UMDA
		50.0	ML	0.00	794.81	470.20	0.00	0.00	0.00	0.00	0.00
		100.0	ML	0.00	4652.35	2800.90	0.00	0.00	0.00	0.00	0.00
		200.0	ML	0.00	14339.93	9319.82	0.00	0.00	0.00	0.00	0.00
		500.0	ML	0.00	34307.95	22632.33	0.00	0.00	0.00	0.00	0.00
		1000.0	ML	0.00	47183.96	31126.40	0.00	0.00	0.00	0.00	0.00
AIR	MX	0.1	ML	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
		0.2	ML	0.00	0.97	0.01	0.00	0.00	0.00	0.00	0.00
		0.5	ML	0.00	83.96	27.33	0.00	0.00	0.00	0.00	0.00
		1.0	ML	0.00	410.48	101.02	0.00	0.00	0.00	0.00	0.00
		2.0	ML	0.00	801.10	306.46	0.00	0.00	0.00	0.00	0.00
		5.0	ML	0.00	4760.85	1147.73	0.00	0.00	0.00	0.00	0.00
		10.0	ML	0.00	13947.83	4140.81	0.00	0.00	0.00	0.00	0.00
		20.0	ML	0.00	37172.73	13377.48	0.00	0.00	0.00	0.00	0.00
		50.0	ML	0.00	92469.66	50063.23	0.00	0.00	0.00	0.00	0.00
		100.0	ML	0.00	264664.94	129716.07	0.00	0.00	0.00	0.00	0.00
		200.0	ML	0.00	643588.81	224093.94	0.00	0.00	0.00	0.00	0.00
		500.0	ML	0.00	1369607.87	362104.98	0.00	0.00	0.00	0.00	0.00
		1000.0	ML	0.00	1727481.76	451665.32	0.00	0.00	0.00	0.00	0.00
WTR	AV	0.1	WC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.2	WC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.5	WC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		1.0	WC	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
		2.0	WC	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00
		5.0	WC	0.00	0.99	0.00	0.00	0.00	0.00	0.00	0.00
		10.0	WC	0.00	11.34	0.00	0.00	0.00	0.00	0.00	0.00
		20.0	WC	0.00	104.79	0.00	0.00	0.00	0.00	0.00	0.00
		50.0	WC	0.00	1734.16	0.00	0.00	0.00	0.00	0.00	0.00
		100.0	WC	0.00	7738.87	0.00	0.00	0.00	0.00	0.00	0.00
		200.0	WC	0.00	21801.90	0.00	0.00	0.00	0.00	0.00	0.00
		500.0	WC	0.00	55234.71	0.00	0.00	0.00	0.00	0.00	0.00
		1000.0	WC	0.00	80787.28	0.00	0.00	0.00	0.00	0.00	0.00
WTR	MX	0.1	WC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.2	WC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.5	WC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		1.0	WC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		2.0	WC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		5.0	WC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		10.0	WC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE C-3

ORNL FATALITY ESTIMATION DATA
(AS USED IN MITRE RISK ANALYSIS MODEL) (CONCLUDED)

LOCATION OR DISPOSAL ALTERNATIVE	WIND DIRECTION & POPULATION DISTRIBUTION (AV=AVG,MX=MAX)	'NO-DEATHS' HAZARD DISTANCE (km)	WEATHER CONDITIONS (ML=MOST LIKELY WC=WORST CASE)	STOCKPILE SITES: ANAD	APG	LBAD	NAAP	PBA	PUDA	TEAD	UMDA
		20.0	WC	0.00	258.87	0.00	0.00	0.00	0.00	0.00	0.00
		50.0	WC	0.00	19546.25	0.00	0.00	0.00	0.00	0.00	0.00
		100.0	WC	0.00	52026.41	0.00	0.00	0.00	0.00	0.00	0.00
		200.0	WC	0.00	123487.51	0.00	0.00	0.00	0.00	0.00	0.00
		500.0	WC	0.00	187603.55	0.00	0.00	0.00	0.00	0.00	0.00
		1000.0	WC	0.00	224169.01	0.00	0.00	0.00	0.00	0.00	0.00
WTR	AV	0.1	ML	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.2	ML	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.5	ML	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		1.0	ML	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
		2.0	ML	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00
		5.0	ML	0.00	2.34	0.00	0.00	0.00	0.00	0.00	0.00
		10.0	ML	0.00	29.18	0.00	0.00	0.00	0.00	0.00	0.00
		20.0	ML	0.00	266.33	0.00	0.00	0.00	0.00	0.00	0.00
		50.0	ML	0.00	4028.32	0.00	0.00	0.00	0.00	0.00	0.00
		100.0	ML	0.00	18020.68	0.00	0.00	0.00	0.00	0.00	0.00
		200.0	ML	0.00	48599.79	0.00	0.00	0.00	0.00	0.00	0.00
		500.0	ML	0.00	104234.76	0.00	0.00	0.00	0.00	0.00	0.00
		1000.0	ML	0.00	143354.78	0.00	0.00	0.00	0.00	0.00	0.00
WTR	MX	0.1	ML	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.2	ML	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.5	ML	0.00	17.11	0.00	0.00	0.00	0.00	0.00	0.00
		1.0	ML	0.00	67.78	0.00	0.00	0.00	0.00	0.00	0.00
		2.0	ML	0.00	96.96	0.00	0.00	0.00	0.00	0.00	0.00
		5.0	ML	0.00	538.65	0.00	0.00	0.00	0.00	0.00	0.00
		10.0	ML	0.00	1542.20	0.00	0.00	0.00	0.00	0.00	0.00
		20.0	ML	0.00	587.05	0.00	0.00	0.00	0.00	0.00	0.00
		50.0	ML	0.00	40145.14	0.00	0.00	0.00	0.00	0.00	0.00
		100.0	ML	0.00	115353.12	0.00	0.00	0.00	0.00	0.00	0.00
		200.0	ML	0.00	202250.92	0.00	0.00	0.00	0.00	0.00	0.00
		500.0	ML	0.00	281283.72	0.00	0.00	0.00	0.00	0.00	0.00
		1000.0	ML	0.00	313736.86	0.00	0.00	0.00	0.00	0.00	0.00
*** Total ***		37776.0									

- o The fourth column, **WEATHER CONDITIONS**, indicates the meteorological conditions, as defined in Table B-1:
  - **ML**: signifies "most likely" weather;
  - **WC**: signifies "worst case" weather.

- o Columns 5 through 12, each labeled with the three- or four-letter site code for the eight storage/disposal sites, contain the potential fatality estimates appropriate to that site and associated with a potential accident having a 'no-deaths' hazard distance, weather conditions, demographic assumptions, and location/disposal alternative as given by columns 1 through 4. The sites are identified by the following codes:

  - **ANAD**: Anniston Army Depot, AL
  - **APG**: Aberdeen Proving Ground, MD
  - **LBAD**: Lexington-Blue Grass Army Depot, KY
  - **PBA**: Pine Bluff Arsenal, AR
  - **NAAP**: Newport Army Ammunition Plant, IN
  - **PUDA**: Pueblo Depot Activity, CO
  - **TEAD**: Tooele Army Depot, UT
  - **UMDA**: Umatilla Depot Activity, OR

For the transportation corridors, the fatality estimates for the maximum population/worst wind direction cases (**WIND DIRECTION & POPULATION DISTRIBUTION = MX**) include consideration of the maximum fatality estimates for the originating site and the destination site as well as for whichever of the following six population centers fall along the corridor:

- o Bend, Oregon (BEND)
- o Baltimore, Maryland (BALT)
- o Jackson, Tennessee (JKSN)
- o Terre Haute, Indianna (TRHT)
- o Salt Lake City, Utah (SLCU)
- o Chesapeake Bay Bridge Tunnel (CBBT) (water shipment from APG only).

The applicability of these population centers to the two rail transportation alternatives is indicated by the asterisk entries in Table C-4. Fatality data for these major population centers is presented in Table C-5.

TABLE C-4

MAJOR POPULATION CENTERS[1]
AFFECTED BY INDIVIDUAL STOCKPILE MOVEMENTS

		AFFECTED POPULATION CENTERS[1]					
STOCK-PILE (SITE)	DISPOSAL ALTERNA-TIVE	BALTI-MORE (MD)	BEND (OR)	JACKSON (TN)	TERRE HAUTE (IN)	SALT LAKE CITY (UT)	CHESPKE BAY BRG TUNNEL (VA/MD)
ANAD	RAIL(NTL)			*		*	
APG		*				*	
LBAD						*	
NAAP					*	*	
PBA						*	
PUDA						*	
TEAD							
UMDA			*				
ANAD	RAIL(RGL)						
APG		*		*			
LBAD				*			
NAAP				*	*		
PBA				*			
PUDA						*	
TEAD							
UMDA			*				
APG	WATER						*

- - - - - - - - - - - - - - - - - - - -

1 In addition to originating and terminating sites for each transport operation

TABLE C-5
FATALITY DATA FOR
MAJOR POPULATION CENTERS
ALONG TRANSPORTATION CORRIDORS

LOCATION OR DISPOSAL ALTERNATIVE	WIND DIRECTION & POPULATION DISTRIBUTION (AV=AVG,MX=MAX)	'NO-DEATHS' HAZARD DISTANCE (km)	WEATHER CONDITIONS (ML=MOST LIKELY WC=WORST CASE)	MAJOR POPULATION CENTERS: CBBT	BEND	BALT	JKSN	TRHT	SLCU
RAR	MX	0.1	ML	0.00	0.00	0.00	0.00	117.64	0.00
RAR	MX	0.2	ML	0.00	5.05	0.97	0.00	352.92	0.00
RAR	MX	0.5	ML	0.00	15.16	83.96	121.36	352.92	27.33
RAR	MX	1.0	ML	0.00	20.79	410.48	413.51	497.76	101.02
RAR	MX	2.0	ML	0.00	53.55	801.10	433.31	1372.61	306.46
RAR	MX	5.0	ML	0.00	340.15	4760.80	896.96	1856.88	1147.73
RAR	MX	10.0	ML	0.00	832.44	13947.83	1668.98	3507.96	4140.81
RAR	MX	20.0	ML	0.00	1740.21	37172.73	3143.93	5225.55	13377.48
RAR	MX	50.0	ML	0.00	3158.30	91130.47	7278.90	9305.29	50063.23
RAR	MX	100.0	ML	0.00	6382.34	231699.29	15336.08	17429.74	129716.07
RAR	MX	200.0	ML	0.00	9567.37	643588.81	27070.22	37089.82	224093.94
RAR	MX	500.0	ML	0.00	14991.35	1239859.23	43760.03	74574.11	299983.91
RAR	MX	1000.0	ML	0.00	16156.40	1589158.55	57964.77	82164.90	310971.17
RAR	MX	0.1	WC	0.00	0.00	0.00	0.00	117.64	0.00
RAR	MX	0.2	WC	0.00	5.05	0.02	0.00	117.64	0.00
RAR	MX	0.5	WC	0.00	15.16	83.96	121.36	352.92	27.33
RAR	MX	1.0	WC	0.00	20.79	150.34	413.51	497.76	99.76
RAR	MX	2.0	WC	0.00	36.32	697.56	431.05	1263.04	211.74
RAR	MX	5.0	WC	0.00	176.95	3440.65	708.84	1619.45	893.50
RAR	MX	10.0	WC	0.00	436.03	7645.14	893.21	2079.92	2272.02
RAR	MX	20.0	WC	0.00	1007.95	19959.93	1695.08	2988.52	6281.94
RAR	MX	50.0	WC	0.00	1761.62	48472.42	3736.17	5422.48	23370.27
RAR	MX	100.0	WC	0.00	3445.52	116267.38	7780.49	8845.11	73116.38
RAR	MX	200.0	WC	0.00	6048.88	273516.83	14967.01	21990.46	120769.73
RAR	MX	500.0	WC	0.00	9497.80	746560.90	28002.03	63166.12	228192.46
RAR	MX	1000.0	WC	0.00	12401.32	994236.32	36308.94	59594.78	245979.16
RAN	MX	0.1	ML	0.00	0.00	0.00	0.00	117.64	0.00
RAN	MX	0.2	ML	0.00	5.05	0.97	0.00	352.92	0.00
RAN	MX	0.5	ML	0.00	15.16	83.96	121.36	352.92	27.33
RAN	MX	1.0	ML	0.00	20.79	410.48	413.51	497.76	101.02
RAN	MX	2.0	ML	0.00	53.55	801.10	433.31	1372.61	306.46
RAN	MX	5.0	ML	0.00	340.15	4760.80	896.96	1856.88	1147.73
RAN	MX	10.0	ML	0.00	832.44	13947.83	1668.98	3507.96	4140.81
RAN	MX	20.0	ML	0.00	1740.21	37172.73	3143.93	5225.55	13377.48
RAN	MX	50.0	ML	0.00	3158.30	91130.47	7278.90	9305.29	50063.23
RAN	MX	100.0	ML	0.00	6382.34	231699.29	15336.08	17429.74	129716.07
RAN	MX	200.0	ML	0.00	9567.37	643588.81	27070.22	37089.82	224093.94

TABLE C-5
FATALITY DATA FOR
MAJOR POPULATION CENTERS
ALONG TRANSPORTATION CORRIDORS (CONTINUED)

LOCATION OR DISPOSAL ALTERNATIVE	WIND DIRECTION & POPULATION DISTRIBUTION (AV=AVG,MX=MAX)	'NO-DEATHS' HAZARD DISTANCE (km)	WEATHER CONDITIONS (ML=MOST LIKELY WC=WORST CASE)	MAJOR POPULATION CENTERS: CBBT	BEND	BALT	JKSN	TRHT	SLCU
RAN	MX	500.0	ML	0.00	14991.35	1239859.23	43760.03	74574.11	299983.91
RAN	MX	1000.0	ML	0.00	16156.40	1589158.55	57964.77	82164.90	310971.17
RAN	MX	0.1	WC	0.00	0.00	0.00	0.00	117.64	0.00
RAN	MX	0.2	WC	0.00	5.05	0.02	0.00	117.64	0.00
RAN	MX	0.5	WC	0.00	15.16	83.96	121.36	352.92	27.33
RAN	MX	1.0	WC	0.00	20.79	150.34	413.51	497.76	99.76
RAN	MX	2.0	WC	0.00	36.32	697.56	431.05	1263.04	211.74
RAN	MX	5.0	WC	0.00	176.95	3440.65	708.84	1619.45	893.50
RAN	MX	10.0	WC	0.00	436.03	7645.14	893.21	2079.92	2272.02
RAN	MX	20.0	WC	0.00	1007.95	19959.93	1695.08	2988.52	6281.94
RAN	MX	50.0	WC	0.00	1761.62	48472.42	3736.17	5422.48	23370.27
RAN	MX	100.0	WC	0.00	3445.52	116267.38	7780.49	8845.11	73116.38
RAN	MX	200.0	WC	0.00	6048.88	273516.83	14967.01	21990.46	120769.73
RAN	MX	500.0	WC	0.00	9497.80	746560.90	28002.03	63166.12	228192.46
RAN	MX	1000.0	WC	0.00	12401.32	994236.32	36308.94	59594.78	245979.16
WTR	MX	0.1	ML	0.00	0.00	0.00	0.00	0.00	0.00
WTR	MX	0.2	ML	0.00	0.00	0.00	0.00	0.00	0.00
WTR	MX	0.5	ML	0.00	0.00	0.00	0.00	0.00	0.00
WTR	MX	1.0	ML	0.00	0.00	0.00	0.00	0.00	0.00
WTR	MX	2.0	ML	0.00	0.00	0.00	0.00	0.00	0.00
WTR	MX	5.0	ML	0.00	0.00	0.00	0.00	0.00	0.00
WTR	MX	10.0	ML	0.00	0.00	0.00	0.00	0.00	0.00
WTR	MX	20.0	ML	587.05	0.00	0.00	0.00	0.00	0.00
WTR	MX	50.0	ML	40145.14	0.00	0.00	0.00	0.00	0.00
WTR	MX	100.0	ML	115353.12	0.00	0.00	0.00	0.00	0.00
WTR	MX	200.0	ML	202250.92	0.00	0.00	0.00	0.00	0.00
WTR	MX	500.0	ML	281283.72	0.00	0.00	0.00	0.00	0.00
WTR	MX	1000.0	ML	313736.86	0.00	0.00	0.00	0.00	0.00
WTR	MX	0.1	WC	0.00	0.00	0.00	0.00	0.00	0.00
WTR	MX	0.2	WC	0.00	0.00	0.00	0.00	0.00	0.00
WTR	MX	0.5	WC	0.00	0.00	0.00	0.00	0.00	0.00
WTR	MX	1.0	WC	0.00	0.00	0.00	0.00	0.00	0.00
WTR	MX	2.0	WC	0.00	0.00	0.00	0.00	0.00	0.00
WTR	MX	5.0	WC	0.00	0.00	0.00	0.00	0.00	0.00
WTR	MX	10.0	WC	0.00	0.00	0.00	0.00	0.00	0.00
WTR	MX	20.0	WC	258.87	0.00	0.00	0.00	0.00	0.00
WTR	MX	50.0	WC	19546.25	0.00	0.00	0.00	0.00	0.00

TABLE C-5

FATALITY DATA FOR MAJOR POPULATION CENTERS ALONG TRANSPORTATION CORRIDORS (CONCLUDED)

LOCATION OR DISPOSAL ALTERNATIVE	WIND DIRECTION & POPULATION DISTRIBUTION (AV=AVG,MX=MAX)	'NO-DEATHS' HAZARD DISTANCE (km)	WEATHER CONDITIONS (ML=MOST LIKELY WC=WORST CASE)	MAJOR POPULATION CENTERS: CBBT	BEND	BALT	JKSN	TRNT	SLCU
WTR	MX	100.0	WC	52026.41	0.00	0.00	0.00	0.00	0.00
WTR	MX	200.0	WC	123487.51	0.00	0.00	0.00	0.00	0.00
WTR	MX	500.0	WC	187603.55	0.00	0.00	0.00	0.00	0.00
WTR	MX	1000.0	WC	224169.01	0.00	0.00	0.00	0.00	0.00

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